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GEORGE HUNTINGTON WILLIAMS.

As our thoughts turn to George Huntington Williams and we endeavor to express in some fitting form our appreciation of his character as a man and of his ability as a teacher and investigator, we are embarrassed by the sense of our bereavement at his death and of our bewilderment at those inscrutable laws that sometimes deprive us of what we hold best. It would be impossible for one who enjoyed the intimate friendship of such a nature as George Williams possessed to approach his memory by any other avenue than that of the affections, or to recite the achievements of his brilliant mental activities without first recalling those amiable traits that won him a place in the hearts of all his associates.

Gifted with the grace of personal attractiveness that commended him to the favor of new friends and in no way belied his disposition, he was also endowed with a ready adaptability to the conditions and interests of those with whom he was brought in contact, which was greatly enhanced by that happy faculty of letting others share his own interests and of considering them both worthy of his confidence and capable of entering into his pleasures and pursuits. These fundamental elements of good fellowship distinguished him to a marked degree. But he was more than genial; the buoyancy of his spirit which kept him company through periods of anxiety, making him hopeful in adversity, carried him at other times to heights of enthusiasm. The sanguine expectations and superlative qualities that sprang

into being at the magic touch of his unrestrained enthusiasm were irresistible. This quality of his nature contributed very largely to the success of his intellectual labors, and to the inspiriting influence he exerted over his pupils. More than this, it enabled him to carry forward cheerfully the plan of his successful career against the early discouragement of those in authority over him, who subsequently recognized his ability and heartily coöperated to enlarge his opportunities.

One recalls with delight the vivacity and enthusiasm with which he disclosed some new observation, or unfolded schemes that opened up alluring vistas of possible research. But happier yet must always remain the recollection of George Williams as the historian of his own varied experiences. Times without number have we been carried away in merriment over the narration of his last humorous adventure until it seemed that all the incidents of his life must have worn the comic masque. His sense of humor was keen and never deserted him. By it ordinary events became amusing, and the more notable ones ludicrous. Whether his experience was in the class room or the study, dining room or nursery, some one or some thing furnished the text for a humorous anecdote. His excursions often brought him into laughable situations, and his more considerable expeditions became adventures alive with mirth or with ridiculous incidents.

But while stranger and friend alike paid tribute to his humor, his power of interpretation did not transgress the bounds of fairness, or expose its subjects to unjust ridicule. It lacked the sting of satire, and reflected the nobler characteristics of his nature. For above all other traits there shone the strong light of his unselfishness, raised into prominence by a spirit destitute of jealousy. Often did he prove by actions more than words his freedom from jealousy; his generous treatment of his students in their work; the helpful elaboration of their ideas, or of their plans; his successful navigation of those dangerous straits that separate the provinces of director and worker, of principal and assistant—waters in which so many craft become disabled, so many undertakings are hopelessly wrecked; his magnanimous

conduct toward his junior associate, whose advancement he earnestly advocated and materially hastened, and between whom and himself there always existed the closest affiliation and heartiest concord. And when, about to venture upon untried ground, the present writer sought his friend's advice, he found a generous counselor, one ever ready to communicate ideas, observations, and valued knowledge, who seemed incapable of secreting for some fancied gain anything that might benefit another. But higher yet must be recorded the purity of his life — his honor without reproach; his affections above suspicion.

Turning to his career as teacher and investigator we have first to note those faculties he happily inherited, which showing themselves from time to time during his early development at last became his strength and power. Among these was a great love for books, his frequent companions when a child. He was not only fond of studying them, but attempted making them, and soon developed correct habits of reading—close observation and discriminating analysis. These, combined with a good memory, also discriminative, proved invaluable aids to his success as a teacher, as well as to the completeness of his literary work, in which fullness of bibliography and strength of historical treatment are characteristic features.

He had also a faculty for acquiring languages that not only made him proficient in German and French, and well versed in Latin and Greek, but gave him a command over English which was evident in his writings and even more so in his speech. His conversation was fluent, and his ability to express his ideas in a clear, forcible manner rendered him an excellent lecturer and an attractive speaker. His skill in drawing and illumination developed during his school days, and turned his thoughts toward architecture, his choice of professions at the time of his entering college at eighteen. This talent served him well in after life, and contributed no little to his descriptive powers. A healthy inquisitiveness and the habit of close observation supplied the necessary elements of an original investigator, who

needed only an introduction to some of the many fascinating and alluring problems of Nature to become a zealous searcher after her hidden laws. He was the fortunate possessor of good judgment and a logical reason, and exhibited an energy that was constantly taxing his physical endurance.

With this endowment he entered Amherst College, and in time became attracted toward geology, remaining after graduation to pursue its study with Professor Emerson; then to Europe where he visited regions that had become geologically classic; settling in Heidelberg to devote himself to microscopical petrography under Professor Rosenbusch; acquiring at the same time a knowledge of crystallography and mineralogy. Graduating from Heidelberg in 1882, he returned to this country to find an opening for his stored-up energies in the Johns Hopkins University, where he undertook the labors of an Associate in 1883, being made Associate Professor in 1885. From this time on he led his dual life of teacher and investigator, apparently as eager to pursue the one line of activity as he was to carry on the other. And while they maintained the closest relationship to one another, proceeding conjointly, they may without violence be considered separately.

As a teacher he was eminently successful, judged by the interest taken in his courses, and by the character of the students who have graduated in his department, and who now occupy honorable positions, both in the faculties of universities and on the staffs of geological surveys. His methods were advanced and rational. The liberal use of laboratory practice and frequent excursions into the surrounding country brought his pupils in contact with problems as they exist in Nature. And the actual investigations they were themselves able to carry on under his direction rendered them not merely hearers of his words but doers of them; acquiring experience and self-reliance that enabled them to enter at once upon new fields of geological activity.

His influence as a teacher was not limited to his classes, but reached a much larger audience through the medium of his

writings; whether in advocacy of the intimate connection between crystallography, physics, and chemistry; or in proclaiming the achievements of microscopical research in the realm of geology; or in the substantial aid to the study of crystallography which he has bequeathed us in his text-book on the Elements of Crystallography. His natural impulse to disseminate knowledge showed itself in the many reviews and notices of other works, which were thus brought to the attention of a wider circle of readers. His last writings were in connection with Johnson's Universal Cyclopædia and the Standard Dictionary. A complete list of his publications will appear in the current volume of the Bulletin of the Geological Society of America, through the kindness of Professor Wm. B. Clark.

As an investigator he was naturally influenced by the character of his environment, though his researches were in no sense limited or narrow. In a country where geological problems present themselves on every hand, it is likely that an investigator will attack those that are most accessible. And he will be fortunate if he finds himself in a region as diversified and interesting as that in which Professor Williams began his investigations. But while his work took color from its local surroundings, it was by no means confined to the borders of a limited area, or even of the state in which he lived. His interests and acquaintances in other parts of the country, his proximity to Washington, and his early connection with the United States Geological Survey enabled him to carry on his studies in distant places, and in this way to enlarge the field of his observation. Thus, while the major part of his work was prosecuted in Maryland, it extended into Virginia and North Carolina on the one side, and into Pennsylvania on the other. His researches in the Menominee-Marquette region of Michigan, and in the vicinity of Peekskill, N. Y., besides his travels through some of the most instructive regions of Western America, Canada, and Norway, further enriched his geological experience.

This wide range of opportunity furnished him material in part purely mineralogical, in part petrographical, and toward

the latter period of his career broadly geological. And while, by reason of the greater demands on his time of university duties, his earlier investigations lacked comprehensiveness, yet his treatment of whatever material was at hand was thorough and systematic, and his methods of presentation are models of logical arrangement and concise statement. Even his more fragmentary researches often contributed to the elucidation of principles of fundamental importance and of general application. Thus his study of some remarkable pyroxenes led him to the demonstration of the possibility of hemihedrism in the monoclinic crystal system; while his study of certain hornblende and its gliding planes contributed in no small degree to the proper crystallographic orientation of this mineral with reference to pyroxene.

In the realm of petrography he improved every opportunity, whether small or great, to advance the boundary and efficiency of this growing science. The accidental notice of an obscure body of serpentine in Syracuse, N. Y., long since buried by town improvements, and its investigation by modern microscopical methods, led to the complete refutation of the elaborate theory of Dr. T. Sterry Hunt, so far as it related to the chemico-sedimentary origin of this once well-known occurrence of serpentine. The identification of a glass-breccia, now metamorphosed, in the pre-Cambrian crystalline rocks of the Sudbury district, Canada, demonstrated the existence in this region at that geologically early date of volcanic action, whose products differed in no appreciable manner from those of modern volcanoes.

Soon after his establishment in Baltimore he began the study of the rocks of the neighborhood, selecting from among the crystalline schists those most closely allied to massive igneous bodies, and examining their transitions into more and more metamorphosed forms. In thus early attacking the problem of metamorphism he showed the influence of his environment, which received a powerful impetus from the work of Johannes Lehmann, published the year following, in 1884. This he eagerly assimilated, and, appreciating its great value, brought it to the notice

of his fellow countrymen in two reviews. Subsequently he received from Professor Lehmann a suite of specimens demonstrating the correctness of his conclusions, and by this means he became fully alive to the importance of similar methods of investigation for unraveling the complications of metamorphic rocks. This he expressed in his report on the Menominee-Marquette region in the following words: "The recent multiplicity of refined methods for the investigation of crystalline rocks, has opened an almost new field of geological inquiry. The difficult and obscure problems here presented may now be attacked by truly scientific methods. The prophecies which Hermann Vogelsang made in 1867 for the new departure in geology have been more than realized within the last twenty years. The almost new science of petrography may be said to have proved itself capable of rendering, in the study of the crystalline rocks, a service equal to that which palæontology has already given in the deciphering and correlating of the fossiliferous strata."[1]

Later his convictions as to the mission of petrology and the part it is to play in the advancement of geological science found expression in his address before the Worcester Polytechnic Institute, in which he said: "The recent development in the science of the earth consists of the return to the work begun by its earliest pioneers. The old petrographers were right. If we would know the life history of our planet, we must learn the origin, structural relations, and composition of our rocks. We must discover the forces — chemical and physical — which work in and upon them, and we must see *how* they work." Then catching nspiration from that eloquent advocate of the universality of life in matter, Professor John W. Judd, he adds: "It is a question how far the popularly received distinction between dead and living matter can be made amenable to strict definition as long as we know so little of what the so-called 'life force' is. As far as we can judge of the phenomena presented by the organic and mineral worlds, they differ rather in degree than in kind. . . . .

[1] Bulletin 62, U. S. Geological Survey, p. 34.

There is, however, nothing among the recent discoveries of the microscope in regard to rocks so surprising as their delicate adjustment to their environment. We are accustomed to look upon the masses of our mountains as the very type of what is stationary and eternal; but in reality they are vast chemical laboratories full of activity and constant change. With every alteration of external conditions or environment, what was a state of stable equilibrium for atoms or molecules ceases to be so. Old unions are ever being broken down and new ones formed. Life in our planet, like life in ourselves, rests fundamentally on chemical action. The vital fluid circulates unceasingly through the arteries of the oceans and the currents of the air; it penetrates the rocks through the finest fissures and invisible cracks, as the human blood penetrates the tissues between artery and vein, producing, with the help of heat and pressure, like changes in the histology of the globe."[1]

The establishment of these convictions became the ruling motive of his later work. The more important of his petrographical studies include those on the gabbro and diorite in the neighborhood of Baltimore; on the massive rocks of the Cortlandt series in New York; and on the greenstone schists of the Menominee-Marquette region.

As his interests extended into the broader domain of general geology the scope of his investigations widened, and we find him at work on the petrography and structure of the Piedmont plateau in Maryland, and on the occurrence and distribution of the ancient volcanic rocks along the Atlantic seaboard. His work in coöperation with others on the geology of Maryland occupied a large share of his time in recent years, and appeared in various editions of the map of the state, the last of which is now in press.

In recognition of the value of his services to the Johns Hopkins University he was appointed Professor of Inorganic Geology, in 1892. The same year he was honored by the Geological Society of London by being made a foreign correspondent. He was one of the judges of award in the department of mineralogy at

[1] Popular Science Monthly, September, 1889, pp. 640–648.

the World's Columbian Exposition; and was a vice president of the Geological Society of America.

At the height of his effectiveness and in apparent vigor of manhood he was cut off—leaving the fields of his activity to other workers, and leaving us to mourn the loss of an illustrious associate, whose lovable character mellows the memory of his fruitful life.

Another day is ended.—A brilliant sun has set, illumining the clouds that would darken heaven with a vivid coloring, whose varied hues are but reflected fragments of the white light of noon.

JOSEPH P. IDDINGS.

GLACIAL STUDIES IN GREENLAND. II.

The Glaciers of Disco Island.

Very much of the deep interest felt in the glaciation of Greenland springs from the light it throws upon the former glaciation of our own country and of Europe. In the region of the old drift of the middle latitudes, the only glaciers that now exist belong to the small mountain type. These very imperfectly represent the modes of action of continental glaciers. It is natural therefore to turn for light to the polar ice-fields, which alone approach continental dimensions. But this approach to equality in dimensions and similarity in general habit is attended by a possible, if not a probable, difference in the special effects of latitude. If, to be sure, the ancient glaciations were caused by changes of latitude, these differences might not exist. But this hypothesis, like all other hypotheses relative to the origin of ancient glaciation, is at present open to very serious sources of doubt. It is not safe, therefore, to assume like latitudes. The peculiarities of glacial action due to latitude are therefore to be sought out, and, if need be, taken account of in drawing comparisons between the ancient glaciation of low latitudes and the present glaciation of high latitudes.

It is not difficult to find a partial basis for the elimination of these special effects. The great ice-field of Greenland ranges through something more than twenty degrees of latitude, *i. e.*, it stretches from about Lat. 60° N. to a limit but partially known, somewhere beyond Lat. 82° N., according to Lieutenant Peary. The former glaciation of the United States reached somewhat south of Lat. 38° N. It hence appears that the old glaciation stretched just about as far south of the southernmost extremity of the present ice-field of Greenland, as this ice-field now stretches north of that point. The difference between the

more southerly and the more northerly glaciers of Greenland may therefore give us a clue to what may have been the effects of double that range in former times.

The southern extremity of Greenland is, however, affected by the presence of the polar current of East Greenland and its heavy ice pack, which wraps about Cape Farewell and flows up the west coast several degrees, as already described. On this account a comparison between the more genial tracts immediately north of this and those of higher latitudes may be as representative as one drawn between the extreme portions. At any rate, this is the only comparison I can make, as my observations south of Disco Island were extremely limited. So far, however, as their very slight value goes, it appears that the Disco Island glaciers are of the same type as the glaciers of like dimensions in the more southerly region. In the following descriptions an endeavor will be made to call attention to all those peculiarities which seem to be serviceable in distinguishing the special effects of latitude. Among these special effects it is not meant, of course, to include those general influences of low temperature simply as such, to which the glaciation is due, but rather those which are inherent in the latitude as an astronomical relationship; such effects, for example, as may be attributed to the low angle of incidence of the sun's rays, or to its constancy above the horizon, or to similar phenomena involving peculiar effects aside from low temperature.

Politically speaking, Disco Island belongs to "Northern Greenland." Godhaven, the capital of the "northern inspectorate," is located on its southern border. In reality, however, Disco lies south of the middle latitude of Greenland. It ranges in latitude between 69° 15′ and 70° 20′ and in longitude between 51° 70′ and 54° 80′. The glaciers we are to study lie just north of Lat. 69° 15′ N. They are therefore but little within the Arctic circle. They are eight and one-half degrees south of those which we shall study a little later on Inglefield Gulf.

Disco is the largest of the known islands associated with

Greenland. Should the mass of land seen by Lieutenant Peary, north of Independence Bay, prove to be an island, as is highly probable, it will doubtless be found to surpass Disco in extent. The island is essentially a lofty plateau, ranging in height between 2000 and 4000 feet, with peaks rising to 5000 feet. Its borders are generally precipitous, but broken by valleys which are usually narrow and steep, penetrating but short distances. On the western side, however, there are developed very notable amphitheaters by the broadening and mesa-like recession of the upper parts of the valleys. On this side also there are three notable fjords, the Disco, Mellem, and North fjords. The first of these reaches nearly half across the southern portion of the island. The southern face of the plateau, as seen on the approach to Godhaven, is bold but not angular nor serrate. A somewhat symmetrical wall rises precipitously from near the water's edge to the height of 2000 to 2500 feet, where it is surmounted by an undulating plain that appears to represent an ancient surface. The face of the wall is broken at frequent intervals by steeply descending ravines, cut by small streams. The boldness of the frontage appears to be due to the work of the sea, but sea action has not recently been so effective as to prevent the accumulation of very large masses of talus along the foot of the cliffs, accompanied by a measurable recession of the upper part of the wall. The topography plainly indicates an ancient process of leveling, with a base-plane some 2000 feet higher than the present. It also indicates that this did not reach completion, and that a very long interval of greater elevation followed, during which a lower plain now near the sea level was partly developed at the expense of the older one. In this the fjords and deeper channels were cut. The present boldness of frontage toward the sea is probably due to the sea's action subsequent to the formation of the lower plain as may be inferred from its freshness and steepness.

The geological structure in the vicinity of Godhaven is quite simple. At the water's edge, and rarely rising more than 100 feet above it, lies a series of gneisses, resembling in all

general respects those of the Laurentian formation. A low hook of this gneiss running out from the base of the cliffs, and embracing an arm of the sea, forms the little harbor of Godhaven. Although here confined to the horizon of the sea level, it is evident that the gneissic series is more than a simple basement of the island, for the glaciers that come down from the ice cap bring bowlders of gneiss, from which the inference is safe that the series rises to the summit at no great distance back from the sea frontage. Apparently the later rocks are built about a nucleus of ancient gneiss.

Resting unconformably upon the gneissic series is a mass of irregular basic igneous rock, largely a volcanic agglomerate, rising somewhat more than a third of the way to the summit. This is exceedingly irregular in structure. Some parts of it are but a rude agglomeration of very coarse volcanic fragments of the roughest type. Although but obscurely bedded, taken as a whole it constitutes a rude stratum upon which, in turn, rises a very regularly bedded igneous series which constitutes the upper and more symmetrical portion of the cliffs. This series appears to consist of very uniform basaltic flows, separated by clastic volcanic material, a portion of which is a bright red silt-rock, whose high color gives distinctness and conspicuousness to the bedding. This regularity of bedding and the symmetrical degradation of the series, with its brownish aspect, gives it, at a distance, much the appearance of some of the Triassic and Tertiary terranes of brown sandstone.

The sandstone series that is well known to occur in the island was not observed in the immediate vicinity of Godhaven, but a few miles north, in the valley of Blase Dale, it appears abundantly in the drift in places, and may be occasionally seen *in situ*.

Along the sides of the valleys which cut back into the plateau the bedded volcanic series at the top usually gives rise to vertical or steeply sloping faces, while the rough massive agglomerates form irregular embossments in the lower slopes and bottoms of the valleys. The bedded series degrades the more rap-

idly, and retires by stopes, mesa-fashion, with a notable tendency to form amphitheatres. The valleys are therefore well suited to receive and develop glaciers.

The most notable of these valleys in the vicinity of Godhaven is the Blase Dale or Windy Valley. Through this flows the Red River, whose waters are tinged by the débris of the reddish shales and the red part of the igneous series. This valley is perhaps a mile in width, measured between the bluff faces, and is stiffly joined on either hand at nearly right angles by valleys of considerable breadth, but short length. The Blase Dale reaches back almost due northward, with moderate acclivity, for perhaps fifteen or twenty miles. Its full length was not seen, and the maps of the interior are imperfect.

Into the tributaries of this valley three glaciers descend from the west and two from the east, within eight miles of its mouth. The first three are derived from the snow cap which covers the southwestern portion of the plateau; the last two come from a much smaller snow cap on a dissevered portion of the plateau on the opposite side of Blase Dale. The snow cap on the west side of the valley so nearly occupies the plateau immediately overlooking Godhaven, that its border may be seen from the village through a short valley cut by a brook in the face of the escarpment. The base of the ice cap, according to the charts and the descriptions of Dr. Rink, is about 2500 feet above tide. At the time of our visit, both in July and September, it was covered with fresh snow to its very edge. We did not therefore climb to it, as it seemed more profitable to spend our limited time in the examination of the better exposed portions of the glacial tongues derived from it. Three of these glacial tongues were visited. They descend from the snow cap by cataracts across the horizon of the bedded igneous rocks, until they reach the broader, gentler portion of their respective valleys, where they reshape themselves into plump, solid glaciers, and creep on down to points varying from 900 feet to 1500 feet above the sea.

We shall perhaps encounter in their most natural order

those features in which students of American and European drift are most interested, if, instead of beginning our study here, we start at the sea level and follow up the valley until we reach the ends of the present glaciers, as we shall thus see the work formerly done by the once more extensive ice.

The gneissic rocks at the sea level, especially those that surround the harbor of Godhaven and stand out somewhat from the bluffs, are thoroughly smoothed after the well-known fashion of glaciers. They are so well subdued as to constitute an aggregation of fairly well-formed *roches moutonnées*. The ice movement was here from the *eastward*, not from the overhanging ice-crowned cliffs to the north. In other words, the line of motion was tangent to the southern shore of the island, not normal to it. Extremely little drift or débris of any kind has been left upon the surface here. There is abundant evidence of "plucking," and numerous little basins cover the low peninsula south of the harbor, but the material so derived was almost wholly borne away. The principal part of what remains is of the same nature as the rock on which it rests, and hence the erratic material gives us little aid in determining whether the ice movement which wrought upon the surface came down from the interior of the island through Blase Dale, as far as its mouth, and then turned westward at right angles, and crossed this low outlying hook, or whether the movement was part of a more general one from the eastward, caused by a former extension of the great inland ice cap of Greenland, which now has its border some fifty miles to the east. The latter seems to be much the more probable hypothesis, for reasons that will appear later.

On entering the mouth of Blase Dale, it is remarkable that the drift is found to be very scant. This can be attributed to no inability of the valley to retain drift, for its slopes are sufficiently gentle and its streams sufficiently confined to definite channels to permit the retention of drift if it were ever lodged there. Nor can it be attributed to any uncertainty of observation, for the surface is essentially bare. Occasional clumps of willows occur, mosses are somewhat abundant, and there are not

a few flowering plants, all the more noticeable and grateful for their persistent blossoming in spite of the hostile elements, but none of these, nor all together, essentially obscure the surface. Portions of the valley well suited to retain drift are almost entirely free from it. Here and there are some small aggregations, and in some of the valleys there are considerable accumulations, although in some of these instances it is uncertain what part is due to stream action, what to local disaggregation, and what to glacial transportation. But whatever may be the result of a strictly correct analysis of such mixed deposits, the general fact remains that the glacial drift in the valley is exceedingly scant. That there is some, however, is beyond question, for, besides other evidence, there are here and there gneissic bowlders which are sharply distinguishable from the igneous rocks that form the entire botto m and sides of the valley, and these are perched in such situations and have such forms and markings as to show that they are the relics of a glacier that formerly occupied the valley.

The contours of the bottom and lower slopes of the valley have taken on phases consonant with the scant drift. While in general the outlines are referable to meteoric and aqueous erosion, and their general configuration is of the usual degradation type, they are slightly rounded and subdued, after the glacial fashion. A few shallow basins occur, for which no assignable agency other than ice seems available. Nowhere, however, are the spurs, ridges, or other embossments of the valley subdued to a distinct moutonnée type. No glacial striæ were observed, except in the immediate vicinity of the present glaciers. These characteristics prevail throughout the valley up to the immediate vicinity of the present glaciers. No terminal moraine was found stretching across the valley at any point below, but at the ends of the present glaciers notable terminal moraines are being formed. The scantiness of the marks of this former glaciation of Blase Dale, compared with the strong markings on the little Godhaven peninsula, affords grounds for the view already expressed that the glaciation of the latter was a part of a more

general and more powerful movement from the east rather than an extension of the local glaciation of the island.

Ascending Blase Dale amid such feeble tokens of former ice action, and turning to the left into the wide mouth of the first tributary valley, we reach the lowest of the Blase Dale glaciers at a height of about 1500 feet above the sea.

FIG. 6.—Portion of the end of Lower Blase Dale glacier in the west valley, showing terminal slope and the relations of the ice to the morainic material.

Lower Blase Dale Glacier.—This glacier descends from the ice cap by a steep, much-crevassed cataract. An embossment of rock in the center causes the ice to break over it and fall in fragments to the base of the declivity, where it again solidifies and moves on with the branches on either hand that succeeded in descending without complete disruption. These branches correspond to the heads of two valleys that jointly make up the common valley. These diverge gently below the cataract, leav-

ing a broad, low ridge between them. But the glacier is sufficiently massive to embrace them both, and bridge over the intervening divide. The effect of the ridge, however, is a slight incurving of the frontal margin of the glacier in passing over it, and the development of two imperfect terminal lobes, one occupying each valley.

FIG. 7.—Nearer view of a portion of the extremity of the Lower Blase Dale glacier shown in Fig. 6, illustrating the superposition of the ice upon its morainic material.

At the time of our first visit, on the 16th of July, the edge of the ice and the terminal moraine on this divide were not only concealed by snow, but so deeply buried that the limit of the ice and even the existence of the terminal moraine could only be inferred from adjacent exposed portions. On reaching the crest of the glacier, we found that the larger part of its surface also was still buried in snow. In places it even then retained a depth of three feet or more, which greatly impeded progress,

not to say observation. In September, this had entirely disappeared, but, as already remarked, snow still covered the ice cap above and lay upon the cataracts, and to some extent upon the higher lands adjacent, as will be seen by referring to the photographic illustrations. These particulars, which have little importance in themselves, are introduced here to show the climatic conditions under which these glaciers are formed and maintained. They illustrate the extreme shortness of the season

FIG. 8.—Portion of the end of the Lower Blase Dale glacier on the divide between the two valleys, showing the relation of the ice to the morainic material.

during which effective wastage is brought to bear upon the glacier proper. The full inference from this, however, should doubtless not be drawn, because the season appears to have been somewhat more than usually severe.

At the later date, the character and relations of the terminal moraine were fully revealed. On the saddle between the two valleys the moraine was sharply developed as a little ridge lying immediately against the present ice and rising a few feet — rarely the height of a man — above it. In the valleys, the glacier

pushed out upon its moraine, and lay above it, and, at points. even projected over it, so that it was quite impracticable to walk along the edge of the ice on the débris. Figs. 6 and 7 show the relations of the ice to its moraine in the westernmost of the two valleys. Fig. 8 shows the relation of the glacier to its moraine on the divide between the two valleys. In the latter it will be seen that the terminal moraine is but a small bowldery ridge, formed at the immediate foot of the glacier. A little of the snow drift that obscured the whole moraine in July may still be seen at the right of the picture. In the former it will be observed that the morainic material lies directly beneath the edge of the ice. The glacier even projects a little in the central portion, so that the streamlets of water fall free in front of the drift beneath (Fig. 7). There is a débris-bearing horizon in the ice, about fifteen feet above its base, as shown in the figure. This is but the outcropping edge of a layer of dirty ice, which, besides silt, carries pebbles and stones of moderate size, and an occasional bowlder. Below this there is some débris in the ice, but its amount is small. The wash of the silt over the surface as it melts gives an exaggerated impression of its amount in the photographs. A similar statement may be made of the débris on the whole terminal margin of the glacier. At some points there are layers of ice a few inches thick, which are well set with erratic material. This, as it comes to the surface, gives rise to little heaps or ridges upon the ice, at points a few feet back from the moraine. These heaps or ridges present the appearance of having been forced out from the ice, but this is in part due to the fact that the débris covers the ice and retards its melting, so that it comes to take the conical form so well known on Alpine glaciers. When the loose material is cleared away, the débris is usually found to be confined to a thin layer solidly imbedded in the ice. In some instances, however, the débris was found set free by melting for some distance back between the layers of purer ice, and hence it may have been subject to outthrust by the movement of the ice. Certain instances were found in the Inglefield Gulf region where this had undoubtedly

taken place. But, for the most part, this apparent outthrust was seemingly due to differential melting.

Little needs to be added to the photographic illustrations to make clear the nature and disposition of the terminal material. It is aggregated immediately at and under the ice edge. On its external face it is usually heaped about as steeply as the material will lie. It is composed of rocky material mixed with clay. Gravel is occasionally present, but is only a very minor constituent. The mixture of rock and clay is indiscriminate and varying. It differs little from the well-known stony till produced

FIG. 9. Illustration of the bruising, de-angulation and partial rounding of the bowlders of the terminal moraine.

by Alpine glaciers, where the rock element is abundant and the grindings take the form of clay rather than sand, as is the case with most basic igneous rocks. The bowlders are commonly bruised and de-angulated in various degrees. They are sometimes, but not usually, well rounded. In a moderate degree they are polished and striated in typical glacial fashion. The amount of wear, however, is only moderate. It is far less than the average wear suffered by the bowlders of our Pleistocene drift, as would be expected from the shorter transportation. Fig. 9 illustrates fairly well the nature and degree of reduction. This

was taken on the outer slope of the terminal moraine. A few rods from this point an exposed surface of the underlying rock exhibited characteristic grooving and polishing [Fig. 10].

The waters produced by the melting of the edge of the glacier flow over the terminal moraine in little streamlets at various points along its course. To some slight extent, the waters gather between the edge of the ice and the inner side of the moraine, and run for short distances parallel to the ice edge until they find a lower point in the moraine, when they pass across it. As they descend the outer slope, they separate some of the smaller

FIG. 10. Striated surface just outside of the terminal moraine.

fragments from the mass and slightly round them, producing incipient gravel, but, owing to the rockiness of the morainic material and the shortness of the outer slope of the moraine, this work is very trivial. It however, represents a work that attained very great importance on the outer side of some of our ancient moraines.

The formation of the moraine is in itself a demonstration of the movement of the ice, but it gave no indication of vigor of movement. No opportunity was offered for instrumental measurement, but the natural signs of movement were sought with little result. At the time of our first visit, as already remarked, an immense snow drift covered the border of the ice, the moraine, and a portion of the rock surface outside, yet I saw no signs of

the crushing or crumpling of this bridging drift, such as might have been expected had the ice pushed forward to any notable degree during the existence of the drift. And again, our tracks, impressed upon the soft crest of the little moraine only a few feet back from the border of the ice during our July visit, remained intact and undisturbed on our visit in September. I could not see any clear signs of thrust or disruption in the interval. Beyond question some motion must have taken place, but it was so slight as to fail to indicate itself by such signs as these.

Ascending from the moraine to the glacier, the terminal slope of the ice becomes a matter of interest, in view of the comparisons we shall have occasion to make with the glaciers of Inglefield Gulf, eight and a half degrees farther north. On the saddle between the two minor valleys, or, in other words, in the central part of the end of the glacier, the terminal slope of the ice is so moderate as to admit of easy ascent. In the valleys on either hand the slope is such as to forbid ascent except by resort to the ice axe. On the lateral borders the ascent is again more gentle. In no case however, is there a vertical wall of ice; the line of ascent is a beautiful curve. Attention is especially invited to this because it is in consonance with glaciers of lower latitudes, but in contrast with the prevailing habit in the far north.

Within a few rods of the border, a much gentler slope is reached which gradually grows lower until at a distance of perhaps half a mile, it seems even to be reversed and to descend toward the cataract on the border of the ice-capped plateau. Instrumental measures do not however confirm the impression, but such descents in a direction opposite to the movement of the ice do occur, as we shall see presently.

After leaving the immediate vicinity of the terminal moraine the surface is found to be practically free from pebbles and bowlders. A small amount of dust discolors the surface, a part of which has doubtless been blown upon it and a part of which is probably derived from the ice. A few crevasses traverse the portion of the glacier visited; but these are mostly small and longitudinal. In the main they are old and snow-filled.

In a word of summary, it may be remarked that the glacier conforms to the usual habit of Alpine glaciers of low latitudes. Its surface and terminal contours are of the same type. Its débris, where it does not take the form of lateral and medial moraines, is found in the basal portion of the ice, and does not appear at the surface except in the immediate terminal zone.

The Middle Blase Dale Glacier.—To pass from the glacier just described to the next on the west side of the Blase Dale, it is not necessary to descend to the bottom of the valley. A moderate climb over a low intervening spur and a corresponding descent brings us into the open valley partly occupied by the middle glacier. The precipitous sides of this valley diverge at a wide angle. Its bottom is a broad platform stretching from cliff to cliff and extending a half mile perhaps in front of the glacier beyond which it descends by a steep terrace into the Blase valley. The general form and relations of the glacier and its moraines are so well shown in the photographic illustration, Fig. 11, that little need is left for verbal description. In all its essential characteristics it belongs to the same type as the lower glacier. Its moraine is much more massive and better developed. The point of observation is such as to make the moraine in the central and left portions appear to be rather lateral than terminal, but the little medial moraine at the left shows that the direction of movement is essentially normal to the margin, except at the extreme left. The profile shows the crest and terminal slope of the ice, but it fails to bring out the undulatory nature of the ice surface. On ascending the eastern or right hand portion to the first crest, we were surprised to find an actual descent into a very considerable valley, from which the surface again rose to a second crest. In this valley a little lakelet had accumulated. Fig. 12 shows imperfectly the depression of this valley into which one of my companions had descended so far that only his head and shoulders remained visible. Of course the trustworthiness of the illustration depends on the accuracy of the leveling of the instrument, but the formation of the lakelet, and the descent of the streams into it,

FIG. 11. General view of the Middle Blase Dale glacier and its moraine.

are sufficient evidence that its surface slopes in a direction *opposite* to the movement of the ice. An instance will be given later, in the Inglefield Gulf region, where very considerable surface streams were found flowing *directly opposite to the motion of the ice*.

As in the preceding case, almost no drift occurs upon the surface of the glacier except where there are medial moraines.

FIG. 12. View of a portion of the middle Blase Dale glacier showing the undulation of its surface involving a backward inclination.

The material from which the terminal moraine is built is derived from the base or basal layers of the glacier. The elevation of the end of the gracier is approximately 1600 feet above the sea.

Upper Blase Dale Glacier.—Without either descending to the bottom of Blase Dale or climbing over the heights, it is possible to pass up the valley to the next glacier by taking advantage of a terrace shelf that passes along the face of the cliffs. Beyond it connects with a much more considerable terrace which

gradually broadens until it is wider than the Blase valley itself. At a distance of about three miles, a tongue of ice, very much more massive than either of the preceding, descends from the ice cap through a broader and deeper incision of the plateau face, and stretches entirely across the broad terrace just mentioned, and descends its face almost to the bottom of Blase Dale. At the point where it emerges from the cliffs of the upper plateau it develops strong lateral moraines which extend entirely across the high terrace, and even down its edge into the axis of the Blase valley. The outer lateral moraine on the right, bears evidence of greater age than the terminal moraines of the two glaciers already described. It is notably weathered and covered with vegetation in the partial fashion of the region. There is nothing to indicate age beyond a few hundred years, but it is notably older than the exceedingly fresh moraines we have already encountered, as it is also notably more ancient than the fresh lateral moraine that lies within it. Its material is very rocky and angular. Between it and the edge of the ice there is a more complex moraine consisting of several parallel ridges. The inner edge of this is so intimately associated with the margin of the ice, and its material extends out upon the border of the ice to such an extent as to make it difficult to determine just where the one ends and the other begins.

A very notable medial moraine is borne on the back of the glacier some distance out from its southern margin, but it joins the lateral moraine before reaching the terminus of the glacier. The crevasses of this glacier are more notable than those of the preceding, and besides the true crevasses, there are numerous fracture lines traversing some portions of the surface which seem to be due to internal strains that do not demand the opening of the crevice when once formed. They cross the laminæ, or blue bands, of the ice (which here run parallel to the sides) taking a course obliquely *forward* but curving toward the center of the glacier. Their course is thus seen to be the opposite of that of the normal crevasses on the border of a glacier. They are obviously a fine subject for investigation, and I much regret that

time did not permit me to make more full and critical observations.

This glacier terminates on the steep terrace face shortly before reaching the axis of the Blase valley, and does not develop as distinct a terminal moraine as the two lower glaciers. The lateral moraines maintain great strength down to the terminal curvature, and in some degree close in at the end of the glacier. The terminal face of the ice is steep, but not vertical. Débris embraced in the lower part of the ice comes to the surface on this terminal slope as in the preceding cases, but apart

FIG. 13.—View of the Circumvallate glacier, with the Upper Blase Dale glacier and its lateral moraine in the foreground.

from this and the lateral and medial moraines, the surface is generally free from rocky material.

A circumvallate glacier.—Just north of the Upper Blase Dale glacier, and almost overhanging it, is an interesting little glacial lobe, snugly walled in by a sharp, serrate terminal moraine. This will be seen in the central part of Fig. 13, in the saddle between the prominences at the right and left. The view was taken from the south side of the Upper Blase Dale glacier. It is notable chiefly for the sharpness and symmetry of the moraine, and the contrast between it and the rocky surface around it. Outside of this moraine on the right, it will be observed, there is a wind drift accumulation of snow. This is of little moment

here, but it is a phenomenon that acquires much importance in north Greenland, and will invite special consideration because of its peculiar effects on the formation of the terminal moraine. Here it does not appear to exert any influence on the moraine. It illustrates the persistence of the deeper winter snows throughout the summer. There had been a recent fall of snow, as the residue on the adjacent heights testifies, but this accumulation was obviously not due to it. The photograph was taken on September 2.

FIG. 14.—Distant view of the upper east side glacier, seen from the back of the Upper Blase Dale glacier, looking eastward across the Blase Dale valley.

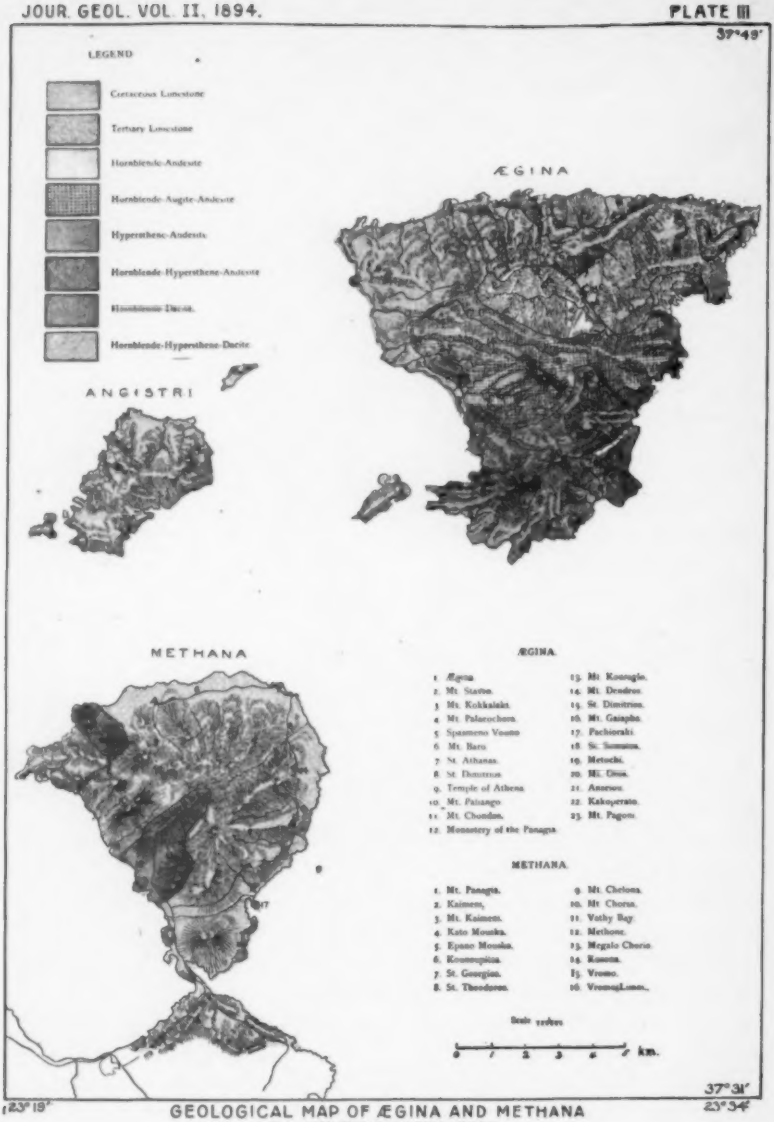
The east side glaciers. — Time did not permit me to visit the glaciers on the east side of the Blase Dale, but Fig. 14 is introduced to show the general aspect and relationships of the uppermost of the two seen on that side. The view was taken from the back of the Upper Blase Dale glacier, looking eastward across the valley. The view also illustrates in some degree the summit topography of the region and the nature of the broad upper valleys into which the ice lobes descend from the still higher ice caps. The east side glaciers give the impression of

great thinness and flatness as compared with those of the west side. This was more notably true of the lower one. They nevertheless have lateral and terminal moraines of small dimensions, but no moraines were seen in the valleys below them.

Comparative features. — The general characteristics of the glaciers of Disco Island are closely similar to the southern Alpine type. They present the same forms of lateral, medial and terminal moraines; the same surface contours; the same terminal slopes; the same freedom from drift on the general surfaces, except as medial moraines, are superposed, or internal drift comes out to the surface on terminal slopes. There is the same habit of forming cataracts on steep descents, and of crevassing at points of more moderate strain. The Disco glaciers differ from typical Alpine glaciers in their less obvious activity. They also differ in that they come from ice caps on relatively flat plateaus instead of amphitheaters or mountain slopes or ravines. This distinction is not absolute, for ice caps occur among Alpine glaciers.

It does not, therefore, appear that these glaciers present any distinctive effects of latitude beyond the results of the low temperature that makes them possible at such moderate elevations. If we shall find a difference in the Inglefield Gulf region, its cause will be one that comes into play chiefly between the Arctic circle and the region far within it, rather than between the Arctic circle and the middle latitudes.

It is prudent to note, however, that these are but local ice caps and local glaciers. The great ice cap of southern Greenland and its dependencies may not have the same habit. At the far north, however, the local ice caps and their dependencies have the same habits as the great inland field and its dependencies. This gives ground for the belief that the features displayed in the Disco region are representative of southern Greenland generally. I have not found the descriptions of the southern Greenland glaciers sufficiently detailed on the points in question to warrant a wholly confident interpretation, but I do not recall anything inconsonant with this. T. C. CHAMBERLIN.



GEOLOGICAL MAP OF ÆGINA AND METHANA
BY HENRY S. WASHINGTON.

A PETROGRAPHICAL SKETCH OF ÆGINA AND METHANA.

PART I.

Introduction.

During several visits to Greece the volcanic island of Ægina and promontory of Methana, which are plainly seen from the Acropolis of Athens, had always presented themselves as a promising field for petrographical investigation. The attractions they held out were enhanced by the fact that since 1867 they have been unvisited, or at least undescribed by a geologist; and as the progress of petrography since that date has been so great, they seemed capable of furnishing much new and perhaps interesting material. An opportunity presented itself in March, 1893, when I was able to devote a week to Ægina and Methana together, with part of a day at Poros. This too short visit was supplemented by a second week spent at the same localities in March, 1894. A day was also devoted to visiting and collecting at Kolautziki, near Kalamaki on the Athens-Corinth Railroad, and at the neighboring valley of Sousaki, with its interesting mofetti. The collections made on these two excursions, which form the basis of this paper, are quite complete and typical of the various eruptive rocks of the region; the total number of hand specimens amounting to 122.

The predominantly petrographical character of the paper here given will explain the very cursory and imperfect way in which many of the geological and stratigraphical features are treated, only such a short sketch and description being given a may be necessary to give the reader a sufficient idea of the general structure.

For the accompanying geological map there was used as a basis the British Admiralty Chart No. 1514, which in Ægina is

very accurate in its delineation of the orographical and topographical features, but leaves more to be desired in the case of Methana. Some names have been altered and some new ones inserted, in accordance with my own notes, but otherwise the map is essentially the same as the original. It is much to be regretted that the construction of a complete and accurate geological map was out of the question, and in its geological features the present map does not claim any great accuracy, and must be regarded as merely an attempt to give the reader a general idea of the relations of the various rock masses, whose boundaries are in many cases more or less hypothetical. Though the roads are bad, traveling (on horseback) is easy, the people are kind and hospitable, and the only impediments are the extreme roughness of the accommodations and the absolute necessity of some acquaintance with the modern Greek language, an accomplishment not very difficult to learn. It must be added that the hypsometric figures, which are expressed in metres, are taken from the Admiralty Chart and from the work of Reiss and Stübel, to be mentioned later.

In conclusion, I must express my warmest thanks to Professor Zirkel for his very kind advice, to Dr. H. Lenk of the University of Leipzig for making the specific gravity determinations for me, and to Dr. A. Röhrig of Leipzig for the care and zeal he showed in making the chemical analyses.

Literature.—A short sketch of the previous geological descriptions of the region must be given, as they will be often referred to. The writings of the travelers prior to 1800 I have not consulted, since their descriptions, while matters of interest, would be of no petrographical value. Among the earliest in this century was Dodwell,[1] who spent a day at the Acropolis of Methana, recognized the volcanic origin of the peninsula, and recommends it to future geologists for investigation. The first really geological investigation was that made by MM. Boblaye and Virlet[2]

[1] DODWELL: Tour Through Greece. London, 1819. II., pp. 281, 284.

[2] Expéd. Scient. de Morée. Sect. des Sci. Physiques. Paris, 1834. Tome II., 2me Part. Géol. et Miner. par Boblaye et Virlet, pp. 239–258 and 364–370. Atlas, 1re Série, Pl. I., III., V., 2me Sér., Pl. IV., V. Referred to as "B. & V."

during the French expedition to the Morea in 1832. Partly owing to its early date their geological descriptions are unsatisfactory, and from several indications, such as speaking of a lava stream at Kaimeni on Methana only as reported by M. de Vaudrimey, they seem not to have explored the region very thoroughly; and their geological sections, both of Ægina and Methana, show many signs of a too free use of the imagination and of the imperfect methods of observation of the time.[1] They express the view (p. 240) that the "trachyte" masses have been raised (*soulevées*) "in a solid or scarcely pasty condition," preceded by the deposition of Tertiary beds. Their descriptions of the various rocks are naturally quite superficial, and in many cases not in accordance with subsequent observations, as when they unite the widely different rocks of Palæochora, Mt. Chondos, and Mt. Oros under one group of "*Trachyte bleu porphyroide*" (p. 252), and state that the "Domite" (the light gray compact hornblende-andesite of Mt. Stavro) owes its character to a discoloration of the blue trachyte (p. 254). In accordance with L. von Buch's theory of Craters of Elevation they attribute this origin to the Spasmeno Vouno, and in part to Methana.

The next geographical traveler was Fiedler,[2] who confined his observations in Ægina to those made on a trip to the temple ruins from the harbor, and at Methana to those made during a sail round the promontory. In the former he devoted his attention chiefly to the clays occurring on the island, though he gives a good description with an illustration (Pl. III.) of Spasmeno Vouno. In Methana he describes one or two of the hot springs, speaks of the Kaimeni stream, placing the crater whence it flowed to the north of it, as he says it is now covered by the sea, and describes the Mt. Panagia, where he states that serpentine occurs. Russigger's account[3] I was unfortunately unable to consult, and the description of Curtius,[4] whose work is largely

[1] Cf. PHILIPPSON, Der Peloponnes., p. 5, who severely criticises their work.

[2] Reise durch Griechenland. Leipzig, 1840. I., pp. 256–278, II., pp. 541–552.

[3] Reisen in Europa, Asien und Afrika. Stuttgart, 1843 and 1848, I., p. 79, IV., pp. 246–251.

[4] Peloponnesos. Gotha, 1851. I., pp. 40–42, II., pp. 438–443.

archæological, is chiefly taken, as far as the geology is concerned, from the writers just quoted.

It was not till 1866 that the region was again visited by geologists, but in this year Fouqué, as well as Reiss and Stübel, on their return from study of the Santorin eruption, examined the localities. Fouqué's account of Methana[1] is short, but he gives an excellent description of the Kaimeni eruptive centre, whose crater he was the first to discover, and which he identified as the site of the eruption mentioned by Strabo, Pausanias, and Ovid.

Reiss and Stübel[2] spent a day on Ægina, going from the harbor to the temple, thence along the eastern slope of the East Ridge to the summit of Mt. Oros, and thence to Perdika; and a little longer time on Methana, of which they explored the northwestern part, including Kaimeni and Mt. Chelona. Their account is very readable, their descriptions, as far as they go, very good, and the conclusions they draw from their observations in general, just. A short petrographical description of the rocks collected by them is given by v. Fritsch, which, being based almost entirely on a megascopical examination, is necessarily imperfect and unsatisfactory. They also give a geological map, which, however, does not go into details, and which is not correct in its orographical features, their changes of the British Admiralty Chart (which they complain of) being much for the worse. They are incorrect also in assigning the limestone mountain masses of the north of Ægina to the Tertiary rather than to the Cretaceous period. Neumann and Pertsch[3] devote some space to this region, but their account is entirely taken from the three preceding writers, as is the case with Philippson,[4] whose field of study did not include Ægina, and who did not visit Methana.

[1] Les Anciens Volcans de la Grèce. Revue des deux Mondes, LVIII., 1867, 470. Also cf. C. R. LXII., 904, 1121.

[2] Ausflug nach Ægina und Methana. Heidelberg, 1867, 84 pp. Ref. in Neu. Jahrb., 1868, 212.

[3] Phys. Geogr. v. Griechenland. Breslau, 1885.

[4] Der Peloponnes. Berlin, 1892.

GENERAL DESCRIPTION.

Ægina.—This island, whose culminating point, the summit of Mt. Oros, lies in Lon. 23°30′ E., and Lat. 37°42′ N., has almost the shape of an equilateral triangle, the north coast running east and west. The length of each of the sides is about 13 kilometres, and the total area about 85 sq. kilometres. The view presented by the island from the sea is striking, the dark gray bare slopes rising steeply from the low northern shore to the central heights, which in turn are joined by a fine curve with the sharp dominant peak of Mt. Oros, the last falling away in a long regular slope to the sea at Cape Pyrgos. The chief port and only town, likewise called Ægina, lies near the northern end of the western shore, the small harbor, formed by two jetties, being crowded with the gaily painted feluccas and other craft of the sponge fishers. It is a picturesque, prosperous little town of some 2500 inhabitants, one of the chief seats of the sponge fisheries of the Ægean Sea, and the centre of quite an extensive native trade in pottery, the Ægina jugs and vases being highly esteemed throughout Greece.

Geologically the island is divisible into five distinct districts, the first being the low fringing shore land on the north and northwest, the latest in point of geological time. The second is the mountainous region of the north and northeast, made up of Mts. Kokkalaki, Baro, the Temple Ridge, and Mt. Paliango, which are all of hard crystalline limestone of undoubted Cretaceous age. The next district is that comprising Mts. Stavro, Palæochora, and Spasmeno Vouno, and may be called for convenience the Stavro District. It is entirely composed of eruptive material, the characteristic rock being a light gray hornblende-andesite. The fourth district is the most complex, both topographically and lithologically. It embraces the ridges of Mts. Chondos, Dendros, Pagoni and Gaiapha, with some outlying spurs, as well as perhaps the north and south running line of hills called Mt. Kourágio. This district, which includes all the central part of the island, may be called the Monastery District (from the Monastery of the Panagia or Virgin in the centre). Litholog-

ically it is chiefly characterized by the abundance of hornblende-augite-andesite. The fifth and last district, made up of Mt. Oros and its outliers, and to be known as the Oros District, occupies the whole southern angle of the island. Orographically, the subordination of the outlying members to a main central mass is much more clearly marked here than in the other cases. The main rock mass is an augite-hypersthene-andesite with later eruptions of dacite.

It may be mentioned here that neither on Ægina nor on Methana did I meet with any dikes, sheets, or other such intrusive bodies: the bearing of which point on the eruptive character of the region will be discussed later.

The north and northwest shores are low and flat, rising very gradually to the foot of the east and west running mountain range. This shore land, which is of late Tertiary age, is composed of horizontal beds of marl and a soft cream-colored limestone, such as is known throughout Greece as "Poros Stone" (πώρινος Λίθος), which is extensively used for building purposes, being soft and easily cut when first quarried, but hardening considerably on exposure. Along the north coast these beds give place to a breccia of limestone blocks cemented by a soft calcareous cement, which occupies the foot of the mountain range just mentioned.

This range, which belongs to the second district, embraces the mountains of Kokkalaki, Baro (199 m.), and the ridge (191 m.) on which stand the well-known ruins of the ancient Greek temple of Athena. These mountains are carved out of nearly horizontal beds of the gray or yellowish crystalline Cretaceous limestone (containing rudistes) which forms such a prominent geological feature of this part of the Balkan peninsula. The southern side of Mts. Kokkalaki and Baro is quite steep, the lower part being in places almost perpendicular—evidently an old shore cliff, the lower part of which is now invisible. On the south slope of Mt. Baro there crops out a horizontal stratum of dark red shale, and a similar, though smaller outcrop is seen near the west end of Mt. Kokkalaki. (Cf. Fiedler, I., 273.)

The limestone is continued to the southeast, as far as Mt. Paliango, forming horizontal beds, in places one or two metres thick, overlying clays. The small hill on which stands the chapel of St. Dimitrios is formed of beds of this same clay, capped by a thick bed of limestone, and not, as Fiedler says,[1] of reddish trachyte. The lower slopes of the Temple Ridge are covered with an andesitic breccia, similar to that described below, the andesite probably being derived from hills to the northeast, east, and south, which lack of time forbade my visiting, but which had the appearance of being andesite and not limestone. A ready means of discrimination is furnished by the small pine trees, which seem to grow best on a limestone soil. Both in Ægina and Methana the limestone mountains are either covered or plentifully overgrown with the common small Aleppo pine (*Pinus Halepensis*), while the mountains of eruptive material are almost, if not quite, devoid of them. The soft late Tertiary limestone is met with below the temple on the road to the Bay of St. Marina. To the southwest rises the long ridge of Mt. Paliango (or Paraliago), 292 m. above the sea, built up of gray limestone beds, dipping 15° to the southwest. The top is covered with pines, but the sides are steep and rugged, and the lower slopes covered with talus.

With the exception of some small alluvial and beach deposits, the rest of the island is of eruptive origin. These Cretaceous limestone masses must have formed, prior to the eruptions, a small island group, the presence of the breccia of water-worn andesite blocks, and late Tertiary beds of marl, etc., showing that elevation has since taken place. The surrounding smaller islands, Augistri, Moni, Metofi, Lagosa, etc., are to all appearances, made of the same hard Cretaceous limestone.

As we approach, coming from Ægina, the mountains south of the northern limestone ridge we find the Neogene limestone and marls gradually giving place to a coarse breccia of rounded blocks of andesite cemented by a soft white limestone of Tertiary age. These blocks, which vary in dimensions from the size of one's fist to larger than one's head, are of the same rock as that which

[1] Op. cit. I., 274.

forms the neighboring mountains, and seem to represent in part an ancient talus, worn by the action of the sea and subsequently cemented by the travertine-like material which partially forms the shore deposits. This sort of breccia is to be found up to heights of 200 metres.[1]

The most northerly mass of eruptive rock is that of the Stavro District, including the domes of Mts. Stavro (311 m.), Palæochora, and Spasmeno Vouno, and much of the lowest slopes of these is formed of the breccia just described. Mt. Stavro (Cross Mt.), which is formed of a compact mass of hornblende-andesite, presents some interesting peculiarities of structure. As we pass along the west side of the valley, between it and Palæochora we see that its east face, which is very steep above but more sloping below, is cut here and there by vertical joints running east and west. In one place two of these parallel joints are only four metres apart, and the intervening mass has slipped down some two metres, giving rise to slickensides on the two faces of the adjoining rock. The side walls show a columnar structure perpendicular to the vertical face. This columnar structure is very well developed around the whole east and north sides of Mt. Stavro, the irregular columns varying from 15 to 50 cm. in diameter, and on the northeast side dipping towards the southwest. They are cut by many transverse, but not decidedly "ball and socket" joints, one effect being that the east slope of the mountain is quite free from débris, while the north and northeast sides have their lower slopes thickly covered with a talus of angular fragments broken off from the columns above. The columns are often curved, and in some places a sub-spherical structure is developed. The upper part of the north face of the mountain is quite vertical, and shows a peculiar structure which, as it seems rather out of the ordinary, may be briefly described. Two straight vertical joints, running north and south, cut the rock face, and on each side of both of these is a secondary system of curved joints which meet the vertical joints at angles of 45° to 60°, curving downwards and approaching a ver-

[1] B. & V., 258, R. & S., 15.

tical direction as they recede from the latter. These oblique columns are divided transversely by a tertiary joint system, cutting them about at right angles to their direction. The effect of these three systems of cracks is to give to the rock mass a "feather-like" columnar structure. As one goes farther to the northwest along this cliff the andesite is seen to be more and more disintegrated, till finally it becomes a pulverulent andesitic mass, resembling tufa, forming a low saddle running toward the limestone of Mt. Kokkalaki. The south slope of the eastern part of Mt. Kokkalaki is flanked by a mass of gray andesite, like that of the "feathered" cliff. Though covered with vineyards, it has the appearance of being a lava stream which flowed from the Stavro Centre and was hemmed in by the limestone ridge on the north.

The hill of Palæochora (Ancient Village), about 300 m. above the sea, is a striking feature of the landscape; rather conical in shape, with slopes of about 30°, it is covered with the ruins of an old town dating from about the end of the sixteenth century, which was built during the period of Turkish occupation as an inland refuge from the numerous pirates that then infested these seas.[1] It is a picture of desolation; the old house walls, built of the gray andesite, still standing though roofless, and interspersed among the houses are numerous chapels, the largest of which, that of St. Cyriacus, containing some interesting frescoes, is still in use. The lower part of this hill is mainly an andesite conglomerate, but the upper part is compact andesite, though cracked and split into a roughly columnar structure.

Immediately to the southeast of this hill, partly resting on its flank, is one of the most remarkable geological features of the island, the so-called Spasmeno Vouno (Broken Mountain). This is a volcanic dome 300 to 400 m. in diameter, and rising from 50 to 60 m. above the valley to the south of it, which was originally well-shaped, of an almost hemispherical form, with gently curving sides, whose average slope varies from 20° to 30°. It is entirely composed of a coarse breccia of light horn-

[1] Lacroix. Iles de la Grèce. Paris, 1881. p. 513.

blende-andesite, somewhat similar to that of Mt. Stavro, in large angular blocks, with a cement of small pieces and paste of the same material; the whole being rather soft, considerably weathered, and showing no signs of stratification. Many of the blocks show the peculiar sub-vitreous lustre which seems to be characteristic of lava when cracked and broken while cooling from a highly heated condition. The original dome is now to a great extent destroyed, the sides being cut by cracks and deep ravines with precipitous sides, the largest of these running quite across the hill from north to south, while the interior is quite hollow, forming a sort of amphitheatre with precipitous walls of rock. This amphitheatre is a scene of wild beauty, pinnacles and buttresses rising on all sides to heights of six to twenty metres, those towards the south being the highest. Two cases of faulting were seen, the throw being vertically downwards and the slip in one case being a couple of metres. Fiedler[1] apparently attributes the condition of the dome largely to explosive agencies, as he calls it "eine zerborstene Felskuppe." Judging from two examinations of the place, this explanation does not appear to me to be the correct one. For one thing, the surface of the dome and the surrounding ground are quite free from large blocks such as could naturally be expected to have been dropped there by an explosion. Again, the presence of tall slender pinnacles of the not very coherent breccia is quite incompatible with such an explanation. Spasmeno Vouno must be regarded then as a volcanic dome, formed by the outpouring of a partially solidified lava stream, the interstices between the blocks being filled chiefly by more liquid matter or by disintegration of the upper part. The mass cracked on cooling, such as we see a similar andesitic mass to have done at Stavro and Palæochora, and the fissures thus formed served as starting points for subaërial erosion. That this erosion is still going on here at quite a rapid rate is shown by the presence of a niche for the reception of a votive tablet, such as are very frequently met with in Greece, near the top of a slender buttress near the north side of the amphitheatre. This niche, which must

[1] Op. cit., I., 274.

date from Hellenic times, is now quite inaccessible. Much of the eroded material is now to be seen forming a terrace to the south and southwest of the dome, probably the "*sol bombé*" of the French geologists.[1] The deeper erosion of the southern part is explained by the fact that Spasmeno Vouno is formed on the southeast flank of the more compact Palæochora dome, the easily eroded mass of the later outflow being hence deeper toward the south.

The central part of the island is separated sharply from the districts just described by a straight, rather broad valley running about east and west almost across the island, at the bottom of which there flows during the wet season a small stream. In its western part the lower part of this valley is cut in the light hornblende-andesite breccia, while further east it is in limestone. This central part of Ægina—the Monastery District—is chiefly composed of two parallel ridges, having a trend of about North 60° West. The most northerly, called (at least its western half) Mt. Chondos (Near Mountain), runs almost clear across the island, ending at the east in Cape Peninda. Its sides are steep (over 30°) and the upper parts bare and rocky, while the lower slopes are often devoted to vines. As seen from the map the lower part of the north slope is composed of a hornblende-andesite like that of Stavro, while the rest of the ridge is chiefly composed of a compact hornblende-augite-andesite. The relation of the two could not be clearly made out in my somewhat hurried trips, but it seemed probable in places that the former rock overlies the latter. On the north side, near the west end and opposite Mt. Stavro, are beds of gray, pulverulent, fine-grained tuff which overlie the fringing andesite breccia. The dip of these beds varies, in one place being 30° southeast, while in another they are horizontal. A bed of compact brown rock which seems to be silicified tuff is also found farther east near the crest of the ridge, and according to Reiss and Stübel[2] a tuff occurs near the base of the east end, south of Mt. Paliango. A

[1] B. & V., 254.
[2] R. & S., p. 17.

little west of north of the Monastery the ridge of Mt. Chondos is made up of rounded masses of andesite which split up into more or less perfect concentric shells on hammering (perhaps an effect of weathering[1]), and which are cemented by a paste of the same material. Almost due north of the Monastery the top of the ridge has quite the appearance of a lava stream of the type that one sees at Giorgio Kaimeni in Santorini, being composed of sharp, angular blocks tumbled together in great confusion.

The southern ridge, called Mt. Dendros (Tree Mountain) is much shorter, ending at the east in a peak on which stands another chapel to St. Dimitrios. It then bends round to the southeast, enclosing, with Mt. Chondos, a small fertile plain in the northwest corner of which stands the Monastery of the Panagia (Holy Virgin). This plain, which is roughly triangular in shape, is bounded on the east by a ridge which bears the name of Mt. Kourágio, to be described presently. The plain is drained by a stream flowing through a deep valley in its northwest angle. Although at first glance it looks as if this Monastery plain were the site of an ancient crater, yet closer examination of the region fails to confirm this impression.

The branch of Mt. Dendros which bounds the plain on the south is called Mt. Gaiapha and has a height above sea level estimated at 500 metres. The inner (north) side of this is very steep, a mound of talus below and steep cliffs above, the rock being split by vertical cracks running southwest and northeast. The rock is a light reddish hornblende-augite-andesite carrying many of the segregations to be described later. It weathers very easily and is hollowed on the northern face into caves and pockets, some of which are two metres across. The southern slopes are covered with angular blocks and overgrown with grass, thyme, and scrub-oak.

The ridge which bounds the Monastery plain on the east bears the name of Mt. Kourágio, though here as in so many other places the mountain peaks and ridges do not possess very definite names and are often called by different names by differ-

[1] Cf. REYER, Die Enganeen, Wien, 1877, p. 20.

ent inhabitants. The sides are steep and covered with large angular blocks of a compact dark pyroxene-andesite, almost identical with that of Mt. Oros. So great is the similarity that petrographically it belongs to the latter district, while topographically it should be placed in the Monastery district, as it terminates sharply and steeply at its southern end on the 250-metre high saddle connecting the central Monastery district with Mt. Oros. Besides the mountains just described there are a number of subordinate spurs and ridges which belong to this district, such as Mt. Pagoni (Peacock Mountain) and the dacitic ridge near St. Vasili on the west coast.

The southern part of the island is connected with the district just described by the above-mentioned saddle which is flanked by two valleys running respectively west and east. This angle of Ægina is occupied by the dominating mass of Mt. Oros, 540 metres high, with its outlying spurs. This mountain is of quite regular conical shape, near the top the sides sloping at angles of about 35°, and at the south running down to the sea in a long slope of about 15°. The area at the summit of the mountain is not large, and chiefly taken up by a small chapel of St. Elias, this uppermost platform being bounded on the south by steep, but not high declivities. No indications of a crater were to be noted, and the topmost rock is a fine-grained, dark gray pyroxene-andesite, with a quite well developed, phonolite-like system of joints, the rock splitting easily into thin slabs. This structure is also met with in the augite-andesite of St. Somatos on the northeast foot, where are some well-preserved Hellenic walls. The flanks of the mountain are covered with angular blocks, making the ascent and descent very fatiguing. As seen from the map the lowest slopes of the mountain are made up of radiating ridges, most of which seem to be due to erosion, while some may be of the nature of lava streams. A small eruptive dome exists on the east flank near the hamlet of Anzeiou, forming a hill 297 metres high. This is formed of a compact dark hornblende dacite, as is the hill of Kakoperato, another later flank eruptive centre, on the northwest flank near the shore.

Methana.—The promontory of Methana, also called in antiquity Methōnē, lying about 7.5 km. southwest of Ægina, is almost an island, being joined to the mainland by an isthmus barely 0.3 km. wide. Its otherwise almost circular outline is broken on the northwest by the projection formed by the hill of the Panagia, a mass of gray Cretaceous limestone, 210 metres high, and on the south by a similar limestone mass, of which the isthmus is a prolongation. Its shores in general are rocky, though beaches occur in places. The general appearance is extremely rugged and forbidding, the rocky slopes coming down to the water's edge at angles of 25° to 35°, and the whole promontory being a confused agglomeration of bare peaks rising gradually but irregularly to the not very prominent mass of Mt. Chelona in the centre. This exterior impression is heightened on closer examination, arable land being very scarce and the few and poor inhabitants wringing a scanty subsistence out of the stony slopes.

The chief harbor and village is on the southeast coast at Vromo Limni (Stench Harbor), so called on account of the hot sulphur springs (temperature 27° C.), where there is a summer bathing establishment—the only place where tolerable accommodations can be secured. Hot sulphur springs also exist on the northeast coast near Agios Giorgios. Near the shore, on the southwest, are the small walled acropolis and other scanty remains of the ancient Greek capital of the district, which for the sake of clearness will be referred to as Methone, its ancient name, the modern village of Megalo Chorio (Large Village), being perched on the mountain slopes above. The other villages are merely clusters of wretched houses.

Geologically the promontory is simpler than Ægina. The Neogene limestone formation, including the flanking breccias, is wanting, which may be partially explained by the fact that Methana lies in an area of subsidence. Cold[1] has shown that the east coast of the Peloponnesos from Cape Matapan to Hermione has subsided in historical times, and as my guide described columns and ruins lying beneath the sea near Methone, it seems

[1] COLD: Küsten Veränderungen im Archipel. München, 1886, p. 14 and map.

that this line of subsidence must be extended farther north to Methana. We find, as already noted, the same gray Cretaceous limestone as in Ægina, at Mt. Panagia and at the southern end near the isthmus. The junction of this with the eruptive rock in the former place is quite sharp though obscured by talus, but I could find no traces of the metamorphic action of the lava on the limestone which Fiedler describes. The junction on the south is covered by a broad, shallow alluvial valley devoted to cultivation.

The rest of Methana is entirely composed of eruptive material, and, while apparently simpler and not divisible into districts, is less clean cut and well defined in its orographical features than is the case on Ægina. The highest point is the summit of Mt. Chelona (760.7 m.) in the centre, which, however, hardly overtops several of the surrounding peaks. The summit is formed of a ridge of huge angular fragments of rock running east and west. This rock is a hypersthene-andesite, dark gray in color, and very compact and fine-grained, though several fragments show a coarse scoriaceous structure, which was probably the reason why the English officers labeled the peak "extinct volcano" on the chart. The same rock is found at Methone and at Megalo Chorio, and, though the stratigraphical relations were difficult to make out in the short time at my disposal, this mass of rock seems to be older than the surrounding masses of dacite.

On the south, Mt. Chelona is separated from the mountain above Vromo by a broad valley which runs down to the small Vathy (Deep) Harbor on the west coast. The topmost ridge, just spoken of, forms the southern boundary of a small plain in which are the remains of a "bee-hive" tomb similar to those at Mycenæ and elsewhere. This plain slopes down to a long valley on the north which separates Mt. Chelona from several peaks almost as high as itself, on one of which are the ruins of an old castle and town as at Palæochora on Ægina, and also bearing the same name. To the east lie several peaks, and in passing from the summit down to Kosona on the east coast one crosses a level plain of some size and

almost circular shape, surrounded by high hills.[1] It has not, however, the appearance of a crater. In the centre of this is a low, flat, circular rocky eminence, about 10 m. high by 80 m. in diameter, composed of a much decomposed pulverulent eruptive rock, originally probably a dacite, carrying many small rounded segregations. Here we have undoubtedly a late centre of eruption. The ridge separating this plain from the sea on the east is covered with large angular blocks of dacite, while the slope below is composed of a dacitic breccia, the cement being a fine-grained tuff-like paste of the same materials.

There remains to be described one more locality which, for several reasons, offers the most important and interesting features of any on the peninsula. This is the hill lying on the northwest coast, east of the limestone of Panagia, called Kaimeni (Burnt); here we have the seat of the most recent eruption of the whole Ægina-Methana region.

The Kaimeni is a ridge about two km. long running northwest from near the hamlet of the same name, forming a promontory in the sea. Its highest point is 416.9 metres above sea level and 206 metres above the small valley at its southern end.[2] Its flanks, which have a slope of 37°, are composed of large and small angular blocks of andesite with some scoria, the latter being especially abundant near the bottom of the southwest flank. At the top is an oval depression, 60 to 80 metres deep and measuring perhaps 100 by 150 metres, its long axis lying parallel with the crest of the ridge. The walls of this depression are very steep, in many places perpendicular, of large blocks of rock or solid cliffs split in places by wide cracks, some of these being fifteen metres deep. The bottom is covered with angular fragments of andesite. This hollow is undoubtedly an explosion crater, but the character of the eruption need not be discussed here. Beyond this crateral cavity the lava stream runs to the northwest projecting into the sea. This seaward part of

[1] This is not the circular "crater-like" plain described by Reiss and Stübel (p. 34), which lies to the northwest of Chelona, and whose crateriform character did not strike me, though I passed through it.

[2] R. & S., pp. 24.

the stream is quite distinct from that just described, being brown and apparently scoriaceous, and weathered into tall pinnacles rendering it almost inaccessible.

This Kaimeni is undoubtedly the site of the last and only historical eruption of the whole region, which occurred during the reign of Antigonus Gonatas, King of Macedonia, 227–239 B. C., and which has been spoken of by Strabo, Pausanias, and Ovid. Pausanias[1] is very brief and merely speaks of hot springs, 20 stadia (2.5 miles) from the small city of Methana, which started during the reign of Antigonus, the water not appearing first, but being preceded by an eruption of fire from the ground. Strabo's[2] account is more explicit and runs as follows: "Near Methone, which is on the Hermionic Gulf, a mountain seven stadia high was cast up during a fiery eruption. During the day it could not be approached on account of the heat and the sulphurous smell, but by night it emitted an agreeable odor and appeared brilliant at a distance; the heat was so great that the water of the sea boiled for five stadia around and was turbid at a distance of twenty stadia. On the hill were found masses of rock as large as towers." Ovid[3] is much more fanciful, and he describes poetically how the winds enclosed in interior cavities, seeking an outlet, finally elevated a mass of rock like a bubble, which was still standing in his day. This poetical description has been brought forward by Humboldt and others in support of von Buch's theory of craters of elevation.[4]

The identification of the site of this historical eruption, which as we have seen is due to Fouqué, is of great importance for many reasons. In the first place it shows us the character of at least one eruption of the region with clearness and certainty. It also, by the state of preservation at the end of the two thousand years which have elapsed since the eruption, furnishes a measure of comparison for the other eruptive centres, and it also gives

[1] PAUSANIAS, II., 34. 1.

[2] STRABO, I., 3. 18.

[3] OVID: Metamorph., XV., 296–306.

[4] Cf. DAUBENY: Volcanoes, London, 1848, p. 327.

us specimens of what we know to be definitely the latest products of eruption.

The fact of an eruption having taken place here in historical times raises the question whether the volcanic forces of the region are extinct, or merely dormant. The hot springs of Methana and probably the mofetti of Sousaki are apparently the last visible signs of volcanic activity, and it seems almost certain that the volcanic forces of Ægina and Methana are quite extinct. But on the other hand, when we recall the long periods of absolute repose that we know to have lasted in some cases between two volcanic eruptions, as that of about seventeen centuries at Ischia, we cannot feel absolutely sure that some time the dormant forces will not be roused, and that we shall not have a fresh chapter to add to the vulcanological history of Methana.

Poros.—The only part of this island (which lies immediately to the southeast of Methana) which is of interest in the present connection is the small promontory on the south coast on which the town of Poros stands, connected with the main part of the island (composed chiefly of Cretaceous slates and limestones) by a low sandy isthmus. This small peninsula is a bare rocky hill, a mass of gray and reddish hornblende-andesite, the difference between the two colors being due only to weathering, as Philippson[1] has pointed out. No traces of a crater are to be seen, and the hill is evidently due to an eruption of the domal type which probably took place in the Quaternary period.[2] Some well-stratified tuff beds, with a dip about 20° to the north, are to be seen near the shore in the town.

Kolautziki.—As my examination of the occurrences of eruptive rock on the mainland of Greece was confined to collecting at the railroad cutting west of the small village of Kolautziki I shall draw largely on Philippson's description.[3] Near Kalamaki, which is on the east side of the Isthmus of Corinth, there is found an eruptive rock which Philippson calls a quartz-trachyte,

[1] Op. cit., p. 46.

[2] PHILIPPSON: op. cit., p. 433.

[3] Op. cit., pp. 21 ff.

but which, judging from the specimens collected farther east is probably more correctly to be called a dacite. The range of hills (chiefly of late Tertiary marls and conglomerates) in which this rock is found runs east parallel with the north shore of the Saronic Gulf and only a few kilometres distant from it. In these hills is the valley of Sousaki[1] with its mofetti. The rocks of this valley are of serpentine and less altered gabbro, and Reiss and Stübel are inclined to attribute the emanation of CO_2 and the other phenomena of the mofetti, not to volcanic agencies, but to the decomposition of the gabbro. Philippson combats this view, and I think correctly, though this is not the place to enter into discussion of the matter. Southeast of this, between the range of hills and the sea, is a low hill land, which is mostly "quartz-trachyte" with marl and conglomerate of late Tertiary and Quaternary age. A little to the west of the hamlet of Kolautziki, nine kilometres east of Kalamaki, the railroad cuts through a mass of this dacite, the width of the cut being 112 metres. This mass of eruptive rock is in general solid and compact, though in places made up of a coarse breccia cemented by finer material of the same nature. No scoriæ was to be seen. As Philippson says, it seems to be the end of a lava stream flowing from the west, though he was unable to find its place of origin. This stream is overlaid by late Tertiary limestone, and hence belongs to the same period as the earlier outflows of Ægina and Methana

CHARACTER AND DATE OF ERUPTIONS.

Before passing on to the petrographical description of the various rocks some space must be devoted to the conclusions that may be drawn from the facts observed by myself and others in regard to the character of the eruptions which formed the masses of Ægina and Methana, their geological date, and the order in which the various rocks were poured out.

In taking up the question of the character of the eruptions we shall start from the most definitely known and least denuded

[1] For descriptions of this interesting and little visited locality cf. Philippson, op. cit., p. 22, and the references there given.

focus, that of the Kaimeni on Methana. Here we have an example of that type of eruption so happily called by Fouqué[1] "cumulo volcanoes." The type specimen of this class of volcanoes is the cone of Giorgio Kaimeni in Santorini, produced by the great eruption which began in February, 1866, and whose formation was closely watched and studied by scientific observers from the beginning to the end.[2] The succession and character of the phenomena in this eruption were briefly as follows: The eruption began as a submarine outpouring of lava and lava blocks, accompanied by few or no explosions. As the mass reached the surface of the sea it was seen that the outflow consisted of a stream of solid angular lava blocks, pouring out slowly and with no explosions till they gradually heaped themselves above sea level, forming a "cone" quite different from any of the well-known types, there being no crater, no stratification of any kind, no tuff, scoriæ, nor ashes, and no flow of liquid lava. It was simply the quiet exudation of a mass of solid angular blocks of eruptive rock, whose rate of progress was slow, not forming streams such as liquid lava forms, but a comparatively short and high agglomeration of loose blocks. Such a cone is also quite different from the also craterless typical *Kuppen* of the Rhine, *puys* of Auvergne or *mamelons* of the Island of Réunion, which are due to the exudation of liquid but pasty material.

A suggestion put forward by Professor J. D. Dana[3] in regard to certain lava streams of Mauna Loa and Kilauea, offers a good explanation of the structure just described. The lava streams called in Hawaii *aa*, are likewise composed of loose angular blocks, and Dana suggests that this structure is due to the lava stream flowing over a region containing subterranean moisture in quantity sufficient to cool and fracture the lava and not be evaporated by the first hot portions of the stream.[4] In the case of

[1] FOUQUÉ: Santorin, Paris, 1879, p. xv.

[2] Cf. FOUQUÉ: Santorin, Cap. II.

[3] DANA: Characteristics of Volcanoes. New York, 1890, p. 243.

[4] I have observed such an action in the glass works at Murano, where a large mass of molten glass was poured into water, with the result that it was cracked into large pieces, much resembling the lava blocks of Giorgio Kaimeni.

the first submarine outpourings at any considerable depth the conditions must be quite different, partly owing to the important factor of the great pressure here involved. But when the lava mass has reached nearly to, or a short distance above, the surface of the sea we get a condition of affairs similar to that suggested by Dana, resulting in the cooling and cracking of the lava stream into solid blocks which are forced upward and onward by the outpouring stream below, forming a cumulo volcano. That there are few or no explosions during this phase of such a submarine volcano may be accounted for by the action of the sea water in cooling and condensing a large part of the imprisoned water vapor, as well as by the presence of the numerous cracks in the mass, serving as so many vents for its outlet.

"Stone streams"[1] due to such a cause differ radically from the ordinary lava streams made up of loose blocks, such as one meets with on Vesuvius or Etna, which are due to a simple mechanical breaking up of the solidified scoriaceous crust by the movement of the mass and the frequent subsequent flowing away of the liquid material.

The eruption may cease at this stage, as at the May Islands in Santorini; or when a certain quantity of lava blocks has been extruded, their mass and height above water varying with the special conditions, the character of the eruption may change, as at Giorgio Kaimeni, to the ordinary type, a crater being formed and explosive ejections of ashes and lapilli, or the pouring out of liquid lava, following.

Now, to return to the Kaimeni of Methana, whoever has seen the two volcanic masses produced by the eruptions of 1866 at Santorini and *ca.* 250 B. C., at Methana, cannot doubt for an instant that the earlier eruption was of the same type as the later. We find at Methana the same short high stream composed of a wild confusion of angular lava blocks, with little scoria. There is also a crater hollow at Methana, which however differs from that at Giorgio Kaimeni[2] in being deeper and with more precipitous

[1] JUNGHUHN: Java, II., p. 762.

[2] For plan of this crater cf. Fouqué: Santorin., Pl. XXX. and Ann. d. Sc. Géol., VII., Pl. 7.

walls, pointing to the fact that at the former place the eruption ceased with the explosion which produced the crater; a conclusion strengthened by the absence of ashes and lapilli, with which the crater and the upper part of the cone of Giorgio Kaimeni are covered.

Such then may be taken as the mode of formation of the earliest and lowest portions of the two areas. As Reiss and Stübel have so well described,[1] we must consider the first eruptions to have formed a cluster of small islands in the sea near the preëxistent limestone islands, such as we find in the analogous case of Santorini at the small Kaimeni Islands in the centre of the bay. These earliest submarine eruptions and some of the later ones took place either just before, or more probably during, the later Tertiary period,[2] as is shown by the andesitic breccias cemented by Neogene limestone.

The analogy between Santorini and our region, however, ceases with the formation of the smaller cumulo volcanoes, for at the former place a large, thoroughly typical strato-volcano was formed, while in the latter the later eruptions seem to have belonged to a different type. These later eruptions were chiefly subaërial and were continued into the following geological period, and even, on Methana, into historical times. They were nearly all eruptions of the dome (*Kuppe*) type—the exudation of large masses of pasty material, accompanied by few explosions and with little formation of tuff or scoriæ, forming high steep mountains or short thick streams. These eruptions did not take place at one centre, but at various points of the region and along fissures forming the complex of hills and mountains that we now see.

That the main mass of both Ægina and Methana is made up of such a complex of volcanic domes, and is not the denuded wreck of a strato-volcano is clearly shown by the following facts: The chief of these is the absence of inter-stratified beds of lava and tuff, and of lava sheets, such as form the chief characteristic

[1] R. & S., p. 39.

[2] Cf. Neumayr. Geol. Bau. d. Insel Kos., etc. Denkschr. d. K. Akad. d. Wiss., Vol. XL., 1880, p. 264; Philippson, Peloponnes., p. 433.

of strato-volcanoes, built up of explosive ejection of fragmentary material and the pouring out of liquid lava streams, of which Vesuvius and Etna are taken as types. Tuff exists, it is true, in some places on Ægina, as we have seen, but here it exists on the surface, overlying the massive rock at the flanks of the mountain, and it is well known that such deposits do accompany volcanic domes. Lava sheets are, however, quite lacking. It is evident from an examination of the region that the denudation has not been very extensive, so that the absence of tuff cannot be explained on this ground; any amount of which, moreover, would not explain the absence of inter-stratified tuff beds and lava sheets. The denudation has not been nearly as extensive as that which has taken place in the somewhat similarly formed Euganean Hills near Padua in Northern Italy, where the eruptions ceased in post-Eocene time,[1] though it must be remarked that the climate is here more favorable to denudation than in our region. The main valleys between the mountain masses must hence be looked on as original intercolline spaces, enlarged, though slightly, by erosion.

The forms of the mountain masses and their mutual positions are decidedly those to be looked for in the case of eruptions of the kind supposed, and different from those produced by the erosion of a strato-volcano. While not of the regular "bell" shape that is seen in such perfection in the "*puys*" of the Auvergnes or the "*mamelons*" of Réunion, yet the shape of the ridges is eminently such as would be produced by the extension of a mass of viscid lava (without the formation of explosion craters) at many points along a fissure, such as have been described by Scrope[2] and Hartung.[3] The masses are higher and shorter than those which would be formed by liquid lava streams, and they do not, except in the case of Mt. Oros, radiate from a common centre.

The character of the lavas also is eminently favorable to the

[1] REYER, Die Enganeen, Wien, 1877, p. 48.

[2] SCROPE, Volcanoes, 2nd ed., 1862, p. 134.

[3] HARTUNG, Beobacht. über Erhebungskrater, etc., Leipzig, 1872, p. 57.

production of domes. Being porphyritic andesites and dacites of medium to rather high acidity they were, when ejected, in a pasty rather than a very fluid condition,—the state of viscosity which is essential to the production of domes and masses of great height as compared with their lateral extensions.

Another fact in favor of the view here held is the total absence of dikes, which are rare in dome eruptions, but common and characteristic in those of the other type. This might, perhaps, be explained by the small amount of denudation, inasmuch as dikes, when present, are much more numerous and of larger size near the base than in the upper layers of volcanoes of whatever type.[1] Their *total* absence, however, cannot reasonably be so explained and, taken in connection with the facts above mentioned, must be regarded as a confirmation of the present view. It may be added that the columnar structure of Mt. Stavro and the laminated structure of Mts. Oros and Chondos, which are characteristic of *Kuppen*, point in the same direction.

It is probable, however, that in some places, streams of more liquid lava were poured out, as east of Mt. Stavro, and perhaps in some of the ridges to the south and east of Mt. Oros, which I was unable to examine. As has already been suggested, there also may have been true craters on Methana, though it does not appear probable to me. These, however, would be secondary phenomena, and we must regard it as certain that the great majority of the eruptions which formed the two regions were of the dome type, as defined by von Lubach,[2] based on a substructure of cumulo-volcanoes, which have also been formed in some of the later flanking secondary eruptions.[3]

Relative age of the various lavas.—It has already been briefly noted, and we shall see at greater length later on, that lavas of quite diverse chemical and mineralogical composition were

[1] Cf. GEIKIE, Text-Book of Geology, 1893, p. 233.

[2] Z. d. d. Geol., Gesell. XVIII., 644.

[3] It is noteworthy that the eruptions of andesites, very similar to those described in this paper, which occurred at Milos (according to Ehrenberg) and at Smyrna, Sipylos and Pergamon (according to my own observations) were all decidedly of the domal type.

erupted at different points of the region under examination, and it is an important matter to ascertain the relative age of these various outflows. To this problem, unfortunately, I can not furnish a very satisfactory or absolutely certain solution, owing to reasons already spoken of and to the scarcity of good exposures and sections; so that the following remarks merely indicate what I believe (though on slight evidence) to be the true state of affairs. I may express the hope that some future observer will decide the question definitely.

In the case of Ægina it is probable that the eruptive activity shifted, as a whole, from south to north. That is, the Oros district is the oldest, followed by the formation of the masses of the Monastery district, and that last of all the hornblende-andesites of the Stavro district were ejected, the formation of Spasmeno Vouno closing the period of eruptive activity on Ægina. This is the general plan, but it is very likely that some of the smaller eruptions, such as those of Anzeiou or Kakoperato, took place during periods when, or between which, the main eruptions of another district were taking place, a fact frequently observed in volcanic regions.

In Methana the sequence of events is less clear than on Ægina, but from analogy with the Ægina rocks and for other reasons, I am inclined to believe that the main andesitic mass of Mt. Chelona was first formed, and that the peaks surrounding it were subsequently ejected. On chemical grounds, which will be discussed on a later page, it seems probable that Methana is, on the whole, younger and more recently formed than Ægina.

HENRY S. WASHINGTON.

(To be continued.)

THE BASIC MASSIVE ROCKS OF THE LAKE SUPERIOR REGION.

IV. THE PERIPHERAL PHASES OF THE GREAT GABBRO MASS OF NORTHEASTERN MINNESOTA.[1]

A. Introduction.

In 1886 Professor J. W. Judd[2] described a series of basic rocks from the Inner Hebrides and the adjoining mainland of Scotland and Ireland, that in mineral composition are closely allied to the gabbros with which they are associated. Their structure, however, is quite peculiar. The most notable difference between it and the structure of a normal gabbro lies in the character of the olivine and diallage constituents. These have "more or less rounded outlines, and are imbedded in a plexus of lath-shaped crystals of feldspar; in polarized light these grains are seen not to be parts of one large crystal, but to have very different orientations. The form of the individuals of pyroxene and olivine at once recalls the structure seen in the granulites" (p. 68). It was therefore called by Judd the "granulitic structure." True gabbros, with the granitic structure, were found only in the central portions of great bosses and flows. On the edges of flows and along their upper and lower surfaces the granitic structure gives place to the ophitic or the granulitic structures. The best examples of the last two types were found: the first in dike rocks; the second in lava flows. Hence the conclusion was reached that "the only type of rock absolutely characteristic of intrusive rocks is the granitic; but ophitic varieties and varieties with skeleton crystals in their base abound in, though they are not confined to, intrusive rocks; while rocks of granulitic structure and those with short and rounded microlites in their groundmass are especially abundant among the

[1] Quart. Jour. Geol. Soc., February, 1886, p. 49.

[2] Continued from Vol. I., p. 716.

lavas" (p. 75). The cause of the granulitic structure was thought to be the crystallization of the rock's components during a period before the internal movements of the rock-mass had ceased. The granitic and the ophitic structures occur only in masses of considerable dimensions, where the original molten magma yielding the gabbro or the diabase, existed for some time in a state of perfect internal equilibrium. It is when crystallization goes on in a mass that is in actual motion, or one whose portions are in motion relatively to each other, in consequence of strains set up in the magma, that a granulation of the augite and olivine results.

The rocks so ably described by Judd in the article referred to, have their exact counterparts in northeastern Minnesota. The great mass of the gabbro constituting the "basal flow" in this region has the typical granitic structure. Along its northern edge, however, near the bottom of the mass, occurs a series of rudely bedded rocks, that differ so markedly from the gabbro that they have been regarded as distinct types by most geologists who have seen them in place. Many of them are dense, heavy, vitreous-looking rocks, others are fine-grained, dark gray ones with a sandy texture and often a resinous lustre, while still others have the appearance of a very fresh, brilliant magnetite. Although they mark the northern limit of the gabbro area throughout its entire extent, their best developments are in the neighborhood of Akeley Lake, in Sec. 29, T. 64 N., R. 5 W.; along the north shore of Iron or Mayhew's Lake, in Secs. 29 and 30, T. 65 N., R. 2 W.; and Sec. 36, T. 65 N., R. 3 W.; in the country between Little Sasaganaga and Gabamichigamak Lakes, in the northwest portion of T. 64 N., R. 5. W., and on the north shore of the lake last named, in Secs. 31 and 32, T. 65 N., R. 5 W. In the reports[1] of the Minnesota survey these rocks are called by various names, such as muscovado, quartzite, iron ore, and in the field notebooks of the members of the United States Geological Survey, quartzites, silicified gabbros, etc. The mere recital of these names is enough to

[1] 15th Ann. Rept., pp. 183, 351, etc. 16th Rept., p. 355, etc.

suggest the obscure relationships of the rocks designated by them.

A rapid glance at the sections of the rocks composing the beds indicates that they may be separated into three classes, of which one, the non-feldspathic gabbros, corresponds to the peridotites[1] associated with the Scottish gabbros. The other two classes embrace granulitic rocks whose structure is similar in all essential respects to the structure of the Scottish rocks referred to above.

The members of one of these two classes are granulitic gabbros, corresponding in their important features with the granulitic gabbros of Professor Judd. The other class of granulitic rocks comprehends a series of quartzose members, composed of quartz and olivine, of quartz and hypersthene, or of the three minerals mentioned. The quartz is evidently not secondary, for the olivine associated with it is almost entirely unaltered in many cases. It has crystallized in its present position, and in most specimens after the olivine was formed. It has been suggested that these peculiar rocks were originally quartzites that have been altered by the great gabbro mass south of them. Many of them appear to have had this origin. They are probably metamorphosed sediments, but of such a unique character that a critical study of them is demanded before a positive decision as to their genesis can be given.

The present communication deals only with the basic and the granulitic gabbros, rocks that are unquestionably phases of the normal gabbro.

B. The Non-Feldspathic Gabbros (Peridotites).

In choosing the group name "non-feldspathic gabbros" for these rocks, in preference to the more usual one "peridotites," emphasis is placed on the fact that the rocks included under it are nothing more nor less than gabbros in which feldspar is lacking. The magma which gave rise to them was undoubtedly a portion of that which, under the ordinary circumstances

[1] J. W. JUDD: Quart. Jour. Geol. Soc. Vol. 41, 1885, p. 357.

prevailing during the period of its cooling, produced the coarse-grained gabbro that covers so many hundreds of miles in northeastern Minnesota. Under certain conditions this same magma yielded the very basic rocks here described, but these form such a small mass as compared with that of the great gabbro, that it does not seem wise to designate them by any name that will not at once indicate their very close relationship to the gabbro. Peridotite as the name of a group of rocks produced by the slow cooling of a very basic magma is well enough, but as a name for the aggregation of basic minerals from a comparatively acid gabbro magma it would be as much out of place as the use of the same name for the olivine-diallage concretions of a basalt.

The rocks of this class occur, as has been said, along the north boundary of the gabbro area, where they are found alternating with the granulitic gabbros of the several varieties. The thickness of the bands ranges from twenty or more feet down to a fraction of an inch only. In a single thin section may sometimes be discovered several of them. The line of separation between the bands is nowhere very distinct, and in the thin section it is seen to be quite gradual. Many times the rocks are so charged with magnetite as to have suggested their being worked for ore. Professor N. H. Winchell,[1] in his discussion of the iron ores of Minnesota, classes this magnetite with that occurring in the normal gabbro under the group name "gabbro-titanic-iron group." The difference between the magnetite of the quartzose beds under the gabbro and of the basic rocks associated with the gabbro is recognized.

A specimen of one of the basic rocks was submitted to Dr. Hensoldt[2] for microscopic study. In the section examined basic and acid bands occur alternately. The basic portion of the rock (M. 1339), which is from the Akeley Lake region, is described as a compact lherzolite, chiefly composed of yellowish-

[1] The Iron Ores of Minnesota, Bull. No. 6, Geol. and Nat. Hist. Survey of Minn., pp. 123–126.

[2] Ib., p. 127.

green enstatite, olivine and magnetite. "Even in the same hand specimen it passes from a fine schistose condition into a coarse crystalline one, while in some of its modifications it assumes the character of a regular quartzite." The schistose portion "shows an admixture of well-defined tabular plates of yellowish-green enstatite, and granular or 'fractured' olivine of a paler shade. The enstatite exhibits an exceedingly fine striation, and it contains no enclosures, except a few grains of magnetite. It polarizes brilliantly, but shows no pleochroism. The olivine is more abundant than the pyroxene. It is present in the form of angular masses and grains, which have a fragmental appearance as if crushed by mechanical pressure or in consequence of a sudden thermal disturbance. The magnetite occurs in rounded grains and crystals, varying from dust-like minuteness to aggregates equaling in size the largest of the enstatite tablets."

Titaniferous Magnetites.—The specimens in the possession of the United States Geological Survey all contain a large proportion of magnetite, which in some cases runs so high as to constitute 90 per cent. of the entire rock. These latter rocks have the bright metallic lustre of magnetite and usually a finely granular texture. The lustre frequently becomes very brilliant and the specimen takes on the peculiar pinkish tinge of ilmenite. A careful inspection of such specimens as seem to be pure ore, reveals the presence in them of tiny yellowish green grains of olivine, but these are so rare that they produce but little impression on the general aspect of the rock. When the magnetite makes up practically its entire body, the rock is much jointed, and, consequently, it easily breaks into small irregular or cuboidal fragments, as Winchell has already noted, and these are not unfrequently natural magnets. Tests of magnetites of this kind from the shores of Little Sasaganaga Lake, N. W. ¼ Sec. 7, T. 64 N., R. 5 W., prove them to be very rich in titanium, as was surmised from their pinkish tinge.

Professor Winchell[1] cites several analyses of titaniferous magnetites from the north edge of the gabbro area, that show from 2.23

[1] Bull. No. 6, Minn. Geol. Survey, p. 141.

per cent. to 16.03 per cent. of TiO_2. He gives no account of their associations, but refers to them simply as gabbro-magnetites. In the same group he includes the magnetite occurring as sand on Black Beach, near Beaver Bay. The rock of Beaver Bay is, however, not a portion of the great gabbro mass that we are now discussing, but it is probably a portion of a sheet or "sill" intrusive in the Keweenawan strata, and occurring at a much higher horizon than that at which the rock which is the subject of the present series of papers, occurs.

Olivine-Pyroxene Aggregates.—When magnetite is scarce in the basal beds of the gabbro, the rocks are usually very fine-grained, sugary aggregates of yellowish green olivine, and a dark brilliant substance that upon examination is found to be a pyroxene. Occasionally a large plate of pyroxene or of hornblende is imbedded in the fine aggregate, but this so rarely happens that it does not affect the general appearance of the rocks. On the other hand it is not uncommon to find in what is apparently a fine-grained mass many large areas of irregular shapes that reflect light uniformly. These evenly reflecting surfaces are the cleavage faces of large grains of pyroxene or of amphibole that are so completely saturated with inclusions as to appear as heterogeneous in structure as the aggregate in which they lie. The entire fracture surface of specimen M. 453H, for instance, is made up of interlocking areas with evenly reflecting surfaces, each covering about a sixteenth of a square inch, and yet so full of little inclusions are they that the rock must be described as possessing a finely granular texture. In very rare cases the thinner bands are very coarsely granular, when they consist almost exclusively of pyroxene with now and then a little magnetite. In all cases the structure is obscurely schistose, and large pieces tend to break more easily along their bedding planes than transversely thereto.

In the most olivinitic phases of these rocks olivine comprises nearly their entire mass. The mineral here occurs in irregular interlocking grains of a pale yellowish green color, crossed by cracks and fissures in which a little limonite or other brown iron

hydroxide has separated. Its inclusions are not abundant. A few tiny grains of plagioclase, a rounded grain of quartz and an occasional mass of leucoxene or flake of pyroxene, besides small irregular grains of magnetite are the only ones noticed.

Here and there, between the olivines, is a plate of pink augite, which is slightly pleochroic and which in most of its characteristics approaches the diallage of the normal gabbro, except that it never contains the gabbroitic inclusions. Its outlines are irregular and its contours are moulded by those of the olivine, so that it is undoubtedly younger than this component. Locally the diallage has acquired a fibrous structure due to alteration into a very pale yellow or colorless mineral supposed to be tremolite (or actinolite).

Most of the latter substance forms groups of fibres, whose relation to the augite can be inferred only from the fact that they occur between the olivine grains, with the contacts between the two minerals quite sharp. The olivine has undergone little, if any, decomposition, so that the fibres must be due to the alteration of the pyroxene, if they are secondary rather than primary in origin. The little groups or bundles of these fibres are very compact except at their ends, where they are frayed out into single fibres whose extinction is sometimes parallel to their long axes, and sometimes is slightly inclined to them. Their double refraction is strong and their polarization colors are brilliant. The axis of least elasticity is nearly parallel to the longitudinal direction of the needles, which are therefore negative, if the orientation of the optical axes is as it is in normal hornblende. Two cleavages are discernible, one parallel to the long axes of the needles and one (a parting) transverse to them. Cross sections of the bundles were not seen, so that it is impossible to say positively that the mineral is a hornblende, but its similarity to certain fibres in other rocks,[1] that are certainly hornblende, is so strong that there can be little question that these are hornblende as well.

[1] Cf. description of actinolite in actinolite-magnetite schists, Amer. Jour. Sci., XLVI., 1893, p. 176.

As to the origin of the supposed tremolite there is a doubt. The assumption of fibrosity by the diallage in some cases, would seem to point to a secondary origin for the bundles of hornblende since this is the only fibrous mineral in the rock. The little bundles, however, are so compact and their situation within the thin section is so remote from that of the diallage that the supposition of a primary origin for them seems to be demanded.

The magnetite, which is much more abundant in these rocks than in the normal gabbro, occurs as inclusions in all their constituents. It is more commonly an attendant of the tremolite, however, than of either the diallage or the olivine. It occurs as small irregular grains between the fibres of the bundles and in the exterior portions of the fibrous groups, and in nearly all cases the longer directions of the grains are parallel to the long axes of the fibres.

In mineral composition these rocks are wehrlites, but their structure is quite different from that of any rocks of this character heretofore described. The diallage and tremolite act as interstitial substances inclosing olivine grains, where the first two minerals are in sufficient quantity to serve this purpose. Where they are absent the rock consists entirely of a mosaic of interlocking grains of perfectly fresh olivine. Since both the olivine and the diallage are identical in characteristics with the same minerals in the normal gabbro, we are led to suspect that the rock is a special phase of the latter, in which the acid constituent —plagioclase— is lacking.

Pyroxene Aggregates.— In other beds the olivine is in less quantity than in those just described, and the rock composing them is slightly different. The olivine is in the same small grains, but these no longer form mosaics. They are in greater part included within large irregular plates of green pyroxene, whose ragged edges extend out for some distance between other surrounding olivine grains. The material of the plates is bright green in color, and it is slightly pleochroic. Its highest observed extinction is 36°, and its most common inclusions are grains of magnetite and masses of limonite. Most of the magnetite is

between the olivine grains and the pyroxene, or in the interstices between the plates of the latter mineral, though some large grains are included within the olivine.

In the non-olivinitic types of these basic rocks, pyroxene and magnetite are the principal components. These types are perhaps more common than the olivinitic types, but their variety is so great that a description of them would be little else than a description of individual specimens. Pyroxene forms the greater part of all these rocks, but the character of the pyroxene changes for each individual bed, so that it is impossible to classify their material with any degree of success. It must therefore suffice to study one of the most striking types, and to leave the others with the statement that they are composed exclusively of some form of pyroxene and of magnetite.

The most interesting of the pyroxene-magnetite rocks is that already referred to as exhibiting lustre-mottling (M. 453 H). In this the pyroxene is present in two forms. It occurs as large, strongly pleochroic green plates, and as small, slightly pleochroic green grains, the latter included in the former. The lustre mottling on the hand specimen is due to the reflection from the large plates, and the fine-grained texture of the rock is the result of the uniform distribution of the small grains within the larger ones. The entire area of a slide is often occupied by four or five of the pleochroic plates, with their inclusions. They interlock with irregular sutures, and thus completely cover the thin section. When examined over the lower nicol the plates are yellowish-pink transverse to their prominent single cleavage and light green parallel to this. The axis of least elasticity in sections showing parallel cleavage lines is in the direction of this cleavage, and the extinction is consequently also parallel thereto. In cross sections the pyroxene cleavage is plainly apparent. Here the pleochroism is in yellowish pink and light wine-yellow tints, the latter in the direction of the smaller of the two lateral axes of elasticity. The absorption is consequently $\mathfrak{c}$=green>$\mathfrak{a}$=yellowish pink>$\mathfrak{b}$=wine yellow. The mineral is in all probability hypersthene.

The small grains included within the hypersthene are bright green in all positions. Now and then slight changes in the shade are noticed, indicating very weak pleochroism. The color is so nearly like that of the green ray of the hypersthene, that the presence of the grains in the latter mineral can be detected only with the greatest difficulty, when the slide is in such a position that the parallel cleavage of this mineral runs in the direction of the vibration plane of the lower nicol. In most of the included grains a well-marked coarse cleavage is noticed, the maxium extinction against which is 41°. In addition to the coarse cleavage there is often observed a second and finer series of cleavage lines, whose direction is parallel to that of the coarser ones. The properties of this pyroxene are those of diallage.

The magnetite in this rock is very abundant. It is in large and small grains imbedded in the pyroxenes, the larger ones usually in the hypersthene and the smaller ones in the diallage. Many of the grains are irregular in shape, but quite a number show crystal forms. There is no evidence that any of the mineral is of secondary origin. It all seems to be original. A portion of the magnetite separated from the powdered rock by digestion with hydrochloric acid was tested for titanium with a negative result, although specimens from other similar rocks contain this element.

The only other constituent observed in the section was a bright green hornblende, whose extinction is not known to be greater than 13°. It occurs in but a few flakes with irregular and indefinite outlines that fade off into the surrounding pyroxenes. It is probably secondary.

A comparison of the descriptions of the types of rocks above given indicates that the hypersthene in the last described type has taken the place of the olivine in the others. The green diallage in both cases is the same, though in the first two instances it surrounds the olivine, *i. e.*, it is younger than this mineral, while in the other instance it is surrounded by the hypersthene —it is older than the latter. A study of the granulitic phases

of the gabbro points to the same conclusion, viz., that the hypersthene and olivine occupy similar places in the rock's constitution. Where the one is present the other is usually absent. They seem to be complementary components. It is also noticeable that when hypersthene is present and olivine absent the rock contains more magnetite than in the case where the conditions are reversed.

In some of the beds the percentage of the iron oxide increases as has already been said, until it reaches 80 per cent. or even 95 per cent. of the rock mass. In some of the sections made from these rocks nearly the entire field of the microscope may be occupied by a single mass of compact magnetite. On its edges this mass often breaks up into small grains that are cemented together by a large plate of green pyroxene. This observation is valuable as showing that the beds composed almost exclusively of magnetite have the same origin as those in which this mineral constitutes only a small part of the rock mass. The latter are certainly phases of the gabbro, hence the former must also be phases of the same rock. Whether most of the magnetite in these varieties is primary or secondary cannot be told. Much of it is certainly primary.

Granulitic Pyroxene Rock.—An interesting variety of the basic rocks is No. M. 1334. It is slightly schistose, and is composed almost exclusively of colorless pyroxene and green hornblende, in small grains with rounded contours. Its structure is granulitic. A brief description of the rock is given in the chapter on the granulitic gabbros.

The Relation of the Basic Rocks to the Normal Gabbro.—From the descriptions that have preceded, it is seen that the basic rocks along the northern periphery of the gabbro are composed almost exclusively of the more basic constituents of the normal rock—viz., magnetite, olivine, and pyroxene. The feldspar of the main mass of the gabbro is entirely lacking in them. The accumulation of the basic portions of the gabbro-magma on its periphery may be accounted for by its differentiation during cooling. Such a differentiation of a gabbro-magma

has been described a number of times. Matthew[1] has noted it in a gabbro area near St. Johns, New Brunswick, while Vogt[2] has described it at a large number of places in Norway, Sweden, and other European countries. A notable feature in connection with the phenomena described by Vogt is the association of oxide and sulphide ores with the basic portions of the differentiated rocks. Many of the magnetite deposits of Norway are shown by this author to be peripheral phases of gabbro. The occurrence in Minnesota is similar to the Norwegian occurrences, and hence the author concludes that the ores of Winchell's "gabbro-titanic-iron group" have a similar origin. It has been shown by the descriptions that this is the case; the basic aggregates on the northern border of the gabbro area are peripheral phases of the coarse-grained olivine gabbro, whose composition and structure are so uniform throughout most of its extent, and the ores associated with these aggregates are only more basic phases of the same magma, by whose differentiation, after its intrusion into its present position, olivine gabbro, pyroxene-olivine aggregates, and almost pure titaniferous magnetite beds were formed.

W. S. BAYLEY.

[1] W. D. MATTHEW: Trans. N. Y. Acad. Sci.

[2] J. H. L. VOGT: Bildung von Erzlagerstätten durch Differentiationsprocesse in basischen Eruptivmagmata. Zeits. f. prakt. Geologie, Januar, 1893.

(To be concluded.)

THE GEOLOGICAL SURVEYS OF ARKANSAS.

The Owen Survey.—The subject of a state geological survey of Arkansas was first brought to public attention by Governor Elias N. Conway in his message to the legislature in 1856. Upon his recommendation the matter was taken into consideration and the first geological survey of the state was begun under an act passed January 4, 1857. This act provided for the appointment of a state geologist by the Governor, and an appropriation of $4,800 per annum, out of which all expenses were to be paid. Dr. David Dale Owen, then state geologist of Kentucky, was appointed state geologist of Arkansas, and entered upon his duties October 1, 1857. The results of the work done in 1857 and 1858 are given in Owen's "First report of a geological reconnoisance of the northern counties of Arkansas," Little Rock, 1858.

In his message to the legislature of 1858–9 Governor Conway recommended more generous support of the survey. There were those in the legislature, however, to whom the collecting of fossils and the examination and location of rocks seemed a ridiculous occupation for state officers to say nothing of its being a waste of the state funds, and every effort was made by them to defeat the appropriation bill.[1]

[1] Some idea may be had of the ridicule heaped upon it from the following extracts from amendments offered to the survey bill.

"Mr * * * offered to amend by adding the following after section 11, viz:

"SEC. 12. The same amount which is appropriated to the State Geologist, shall likewise be appropriated to a phrenologist, * * * * and a like amount to an ornithologist, and their several assistants who shall likewise be appointed by the Governor, and shall continue in office fifty-four years * * *; and the Secretary of State shall forward one copy of each report to the Governor of each state in the Union, except such as may be known to be black republican governors; also, one copy to the Queen of England, and to the Emperors of France and Russia; also, a copy to the Queen of Spain: provided that government will sell Cuba to the United States on reasonable terms."

"SEC. 14. It shall be the duty of the phrenologist to examine and report upon the heads of all the free white male and female citizens in the state, and their children, except such as may refuse to have their heads examined."

The bill providing for the continuation of the survey passed in February, 1859; by its provisions the state geologist's salary was raised from $1,800 to $2,500, and an appropriation of $6,000 per annum was made for the survey work. Under this act Dr. Owen was again appointed state geologist. Before the next legislature convened Dr. Owen died (November 13, 1860) and his "Second report of a geological reconnoisance" was edited by his brother, Dr. Richard Owen, and Prof. J. P. Lesley and was printed at Philadelphia in 1860.

Dr. Owen's efforts were devoted entirely to the work of reconnoissance, the first report treating the region north of the Arkansas River, and the second that south of the river. In the main his ideas of the geological structure of the state were correct, and his facts have been of great service in working out the details of the structure and the areal geology. Errors were made, but they were few and unimportant, especially when we take into consideration the limited time and small means at the disposal of the survey. It may be well to mention the more fundamental of these errors, because they have so long been current:

I. It was thought that the Arkansas coals belonged to the Lower Coal Measures. Coal does occur in the Lower Coal Measures north of the Boston Mountains, and the generalization was made from these beds. The coal of the Arkansas valley is in an altogether different position — near the top of the Coal Measures.

II. It was thought that the novaculites, now known to be Silurian, were Carboniferous. No fossils had then been found in or near the novaculites.

III. The theory of northeast-southwest metalliferous veins across the state, although advanced only as "probable," led to much searching for silver and lead, much loss of time and money, and to much disappointment.

The civil war broke out shortly after the publication of Owen's second report, and all such work was necessarily suspended in the southern states. No steps were taken to finish

the geological survey of Arkansas until after the close of the war.

The Reconstruction Surveys.—In the General Assembly of 1866 a bill was passed by the Senate providing for a geological survey of the state, but it was rejected by the Lower House.[1]

In his message to the General Assembly of 1868 General Powell Clayton, then Governor of the state, recommended the continuation of the survey begun by Owen, but the committee to which the matter was referred reported that "owing to the unsettled state of the country and the lack of funds to prosecute the above work" the bill should be indefinitely postponed.

In the legislature of 1871 a survey bill was passed (and approved March 28, 1871) appropriating $15,000 for two years work. Under this act Governor O. A. Hadley appointed W. F. Roberts, Sr., of Pennsylvania, state geologist. The records in the office of the Secretary of State do not show how long Mr. Roberts held office, but he was appointed June 5, 1871, and in his message to the General Assembly in 1873 Governor Hadley says that he returned to Pennsylvania "last July, and I have not heard from him since."

Dr. George Haddock, then of Arkadelphia, was, upon Governor Hadley's recommendation, appointed Mr. Roberts' assistant, and went with him through the western part of the state.

Mr. Roberts' report was never delivered to the Governor, but, according to his own statement,[2] it was deposited in a bank, because the state was unable to print it. A series of articles, however, was subsequently published by Mr. Roberts in the *Age of Steel* of St. Louis, Missouri (1887–88), and it is probable that these articles represent his views of the geology of the state, and give the results of his work. They are largely a repetition of the results given by Owen.

[1] This bill appropriated $13,000 for the survey for two years — 1867 and 1868. The vote in the House was 30 to 27 against the bill; in the Senate it was 17 to 6 in its favor.

[2] Made to the writer in 1888.

In 1873 Dr. George Haddock, who had been Mr. Roberts assistant, published at Little Rock a pamphlet of 66 pages entitled "Report of a Geological Reconnoisance of a part of the State of Arkansas made during the years 1871–72." This paper gives the only results of the work done under this appropriation.[1] It is of but little or no importance and adds nothing to the work done by Owen.

The General Assembly of 1873 passed a bill for the continuation of the survey, and made an appropriation of $15,000 for it.[2]

Under this act the following state geologists were appointed: *George Haddock*, appointed May 15, 1873, removed from office January 14, 1874. Mr. Haddock, who is said to have been a Scotchman, had been assistant geologist under Mr. Roberts the year before; he made no report except the one published under a former appropriation and mentioned above. *William C. Hazeldine*, appointed January 14, 1874, and removed June 29, 1874. Mr. Hazeldine was an Englishman by birth; he had been sent to the State Legislature from Richmond, Little River county, in 1871. Later he was circuit Judge of the Second District of Arkansas, and lived at Augusta, Woodruff county. As state geologist he made no report, and, so far as can be ascertained, did no field-work. *Arnold Syberg* was appointed June 29, 1874, and remained in office to the end of the term. Mr. Syberg is a native of Prussia; he was at one time a captain in the regular army of the United States, afterwards state engineer of the State of Arkansas, and still later engineer in the Confederate army. He still lives at Little Rock. Mr. Syberg says that he made no report, and that the only work he did was to receive and examine specimens sent or brought in from various parts of the state.

The total amount appropriated for the 1873–74 survey—

[1] The books in the Auditor's office show that $10,700 of this appropriation was drawn out, and that the remaining $4300 was carried over to the next survey account.

[2] For minority report against the appropriation see *Senate Journal*, 1873, p. 450, *et seq.*

$15,000—was spent, and, in addition thereto, the Legislature voted $2386[1] in a deficiency bill.

The failure of the surveys for years 1868 to 1875 to yield any geological results must be attributed to the general demoralization of the state government during the reconstruction period.

No further efforts were made to carry on a geological survey until the year 1881, when bills for such work was defeated in both branches of the General Assembly.

In the Assembly of 1883 the only legislation passed relating to geological work was a Senate concurrent resolution "authorizing and directing the Governor to make application to the Secretary of the Interior of the United States for a geological survey of the State of Arkansas." Nothing seems to have come of this effort to obtain help from the national government.

The Branner Survey.—The last survey of the state was publicly suggested by Governor Simon P. Hughes in his message to the General Assembly in January, 1887, and on January 19th of that year Hon. Elias W. Rector, Representative from Garland county, introduced in the Lower House an act providing for a geological survey of the State of Arkansas.[2]

This bill provided for a state geologist and three assistants. The geologists were to be paid from the appropriation for the state officers, and printing, stationary, postage, fuel, and lights were to be paid for out of funds to furnish supplies and to do printing for state officers, while $10,000 was appropriated in the survey bill proper to pay contingent expenses. The bill required that the survey should be completed in two years. Under this act J. C. Branner, at the time professor of geology in the University of Indiana, was appointed state geologist; he entered upon the duties of his office June 24, 1887.

At the next meeting of the General Assembly, in 1889, there was much and violent opposition to the continuance of the

[1] The biennial report of the State Treasurer for 1874 shows that he paid $19,628 to the state geologist.

[2] It was referred to the Committee on Judiciary, reported back favorably, fully discussed and passed February 24, 1887, by a vote of 53 to 19; the same bill passed the Senate by a vote of 28 to 1, and was approved by Governor Hughes, March 5, 1887.

survey, due chiefly to the fact that the survey had declared fraudulent certain so-called gold mines in the western part of the state; but, under the leadership of Mr. Rector, a bill for its continuation was passed. This new bill was in the form of an amendment of the bill of 1887, and was so worded as to make it unnecessary for subsequent assemblies to do more than vote the money required for the general appropriations. This amendment fixed the contingent fund at $10,000 for two years, and gave the state geologist four assistants in place of the two previously provided for. Under this bill J. C. Branner was re-appointed state geologist. The General Assembly of 1891 made the same appropriations as the previous one, and the same state geologist was again appointed. When this last appropriation was made, it was stipulated that it should finish the survey's work, and that the survey should be brought to a close by the end of March, 1893. When the Assembly met, therefore, in 1893 the field-work had been finished, or as nearly so as possible, and the only appropriations asked for was one to be used to complete the preparations of the reports. For this purpose an appropriation of $4000 was made to be expended under the direction of the Governor. It was understood also that the former state geologist should prepare the reports without expense to the state beyond the assistance he might need in office and clerical work, and that the printing, engraving, and binding of the reports should be paid for as before out of the general appropriations to pay for that work for the state. The reports of the survey are now all published except the four volumes mentioned below.

Some wonder is occasionally expressed that a state geologist should undertake to bring the work of a survey to a definite close, instead of insisting upon the fact that a state geological survey is an essential, and should be a permanent, part of every state government. Whether every state should maintain a permanent geological survey depends upon circumstances and conditions that cannot be discussed in this place. So far as the case in hand is concerned, it seemed, and still seems, better that with

fair appropriations and salaries the work should be pushed energetically and brought to a definite end, rather than that appropriations should dwindle to a point forbidding creditable work. Believing that the people are entitled to what they pay for, it has been the aim of the present survey to meet the reasonable expectations of the people of the state in giving them practical and economic results, and at the same time to do all the purely scientific work that the means at the survey's disposal would admit of, or that the study of economic problems demanded.

The reports are mainly in the form of monographs of the subjects treated: thus all the facts gathered relating to the manganese are brought together in the manganese report; those relating to the novaculites are given in the report on novaculites, and every thing known of the igneous rocks of the state is given in the report on igneous rocks, etc. Besides the evident advantage of having the subjects thus grouped in monographs, this method has kept down the number of volumes, has prevented the publication of undigested field notes, and has greatly reduced the cost of printing. The disadvantages of such a sytem are that the bulk of the work upon a given subject must be done by one person, and, in the case of formations that extend over wide areas and require much detailed study, it is impossible to bring out the results promptly. The clay report, for example, has been in hand since 1887, and is not yet published. The delay in publication is also liable to work injustice to assistants by their results being anticipated. This can be prevented to a certain extent by publishing results of special interest in scientific periodicals.

In the case of the Arkansas survey this method of publication has not been carried out without legal difficulties. The law establishing the survey says: "Section 4. It shall be the duty of said geologist, on or before the first Monday in December of each year . . . . to make a printed report to the Governor of the results and progress of the survey, accompanied by such maps, profiles, and drawings as may be necessary to exemplify the same,

which reports the Governor shall lay before the General Assembly."[1]

Annual reports are the only ones provided for, and it is for this reason that the volumes, instead of being numbered consecutively, are given as annual reports, and divided into volumes, one volume generally being devoted to a single subject.

The greater part of the topographic maps made by the survey will accompany the final report on coal. They embrace an area of 3240 square miles; the maps are on a scale of one mile to the inch, the contour interval is twenty feet. The total area mapped topographically is 4,500 square miles, while topographic sketch maps have been made of about double that area, and special areas have been mapped on scales varying from 300 to 1,000 feet to the inch.

The following are the reports published under the Branner survey.[2]

Annual Report for 1887.—Administrative (pamphlet). Pp. 15.

Annual Report for 1888.

Vol. I.—Gold and silver. Pp. 320+xxxi; 2 maps.
Vol. II.—Mesozoic. Pp. 319+xiv; illustrated; 1 map.
Vol. III.—Coal (preliminary). Pp. 120+x; illustrated; 1 map.
Vol. IV.—Washington county; Plant list. Pp. 262+xiv; illustrated; 1 map.

Annual Report for 1889.

Vol. II.—Crowley's Ridge. Pp. 283+xix; illustrated; 2 maps.

Annual Report for 1890.

Vol. I.—Manganese. Pp. 642+xxvii; illustrated; 3 maps.
Vol. II.—Igneous rocks. Pp. 457+xv; illustrated 6 maps.
Vol. III.—Novaculites. Pp. 443+xx; illustrated; 2 maps.
Vol. IV.—Marble. Pp. 443+xxiv; illustrated; atlas of 6 maps.

Annual Report for 1891.

Vol. I.—Mineral waters. Pp. 144+viii; 1 map.
Vol. II.—Miscellaneous—Benton county; Elevations; River observations; Magnetic observations; Mollusca; Myriapoda; Fishes; Dallas county. Pp. 349+xii; illustrated; 2 maps.

Annual Report for 1892.

Vol. I.—Iron deposits. Pp. 153+x; 1 map.
Vol. II. Tertiary. Pp. 207+xiv; illustrated; 1 map.

[1] Acts of Arkansas, 1887, p. 58.

[2] A bibliography of the Geology of Arkansas is given in Vol. 11 An. Rep. Geol. Survey of Arkansas, 1891, pp. 319-340.

There are also in press or in manuscript four volumes, as follows: The final report on coal; the report on the Lower Coal Measures; the report on clays, kaolins and bauxites; the report on zinc.[1] A bulletin upon the palæontology of the state is being prepared by Dr. H. S. Williams, of Yale University; it will be published by the United States Geological Survey.

The following are some of the general economic results of the Survey's work:

1. The areal and structural geology of the state in so far as the subdivisions are known. (The exact parting between the Carboniferous and Lower Carboniferous along the southern margin of the Carboniferous is not known; indeed it is not known whether the Lower Carboniferous comes to the surface south of the Arkansas River.)

2. Reporting upon the reputed gold mines of the state.

3. Outlining the coal area.

4. Determining and pointing out the adaptabilities of the various coals, and the best methods of mining and marketing them.

5. Showing the extent, value and method of locating manganese deposits.

6. Mapping and calling attention to the character, extent and distribution of the marbles and other limestones.

7. Discovery of chalk, giving its distribution, and suggesting uses to which it may be put.

8. Chemical analyses of the mineral waters.

9. Showing the character of the iron ores.

10. Discovery of bauxite and giving its distribution.

11. Pointing out the character, distribution, and availability of the clays of the state.

12. Determining by tests the character of the granites and giving their distribution.

[1] The survey reports are distributed by the writer to his correspondents at his personal expense and on his own account. Copies can generally be had, however, by geologists and capitalists by addressing the Honorable Secretary of State, Little Rock, Arkansas. It is necessary to state, on making application, that one is a capitalist or a geologist, and interested in the geology of Arkansas, and to prepay all postage or to order the reports sent by express at his own expense.

13. Analyses and distribution of the zinc ores.

Some of the more comprehensive geologic problems that yet remain to be solved, relate to :

1. The palæontology of the state.
2. The physical geography.
3. Quaternary history.
4. Relation of the palæozoic beds to those of the other parts of the continent and to those of the world.
5. The divisions of the Silurian beds.

RESUMÉ OF APPROPRIATIONS AND PUBLICATIONS.

TERM.	GEOLOGIST.	APPROPRIATION.	REPORTS PUB.	VOLS.	PAGES.	MAPS
1857–8	D. D. Owen	$ 4,800	First survey	1	256	0
1858–60	D. D. Owen	12,000	Second survey	1	431	1
1871–3	W. F. Roberts, Sr.	15,000	Haddock's pamphlet	1	63	0
1873–4	Geo. Haddock, W.C. Hazeldine, A. Syberg	19,628	None	0	0	0
Former surveys, seven years.		$51,428		3	750	1

TOTALS OF BRANNER SURVEY.

1887–9	J. C. Branner	$27,800	Reps. for '87–8	5	1105	5
1889–91	J. C. Branner	32,600	Reps. for '89–90	5	2373	21
1891–3	J. C. Branner	32,600	Reps. for '91–2	4	887	5
1893–5[1]	J. C. Branner	4,000	In preparation	4	about 2000	38
	Total,	$97.000[2]		18	6365	69

Engraving, printing, and binding are not included in the total for the period 1887–95. Those items and the cost of fuel, lights,

[1] No field work was done after 1892; the appropriation was made in 1893 for completing the reports.

[2] A deficiency bill for $2,340 was passed by the legislature in 1889. This sum, however, should not be added to the total amount appropriated because a somewhat larger amount reverted to the treasury that year from the appropriation for salaries. It is but just to add, moreover, that the work represented by the state geological reports was not all paid for by the state: about $8000 worth of work was contributed by volunteer assistants; about $5000 was spent on precise levels by the U. S. Coast and Geodetic Survey; about $25,000 was spent in topographic work by the U. S. Geological Survey; about $7000 worth of engraving was done by the U. S. Geological Survey, and a deficiency of about $3000 was paid by the State Geologist.

stationery, and postage would probably bring the total expenditures of the Branner survey up to about $120,000, and the total cost of all the state geological surveys up to $171,428.

When all the conditions are considered, it must be recognized that great credit is due the people of the State of Arkansas for the liberality with which they have supported geological work.

JOHN C. BRANNER.

STANFORD UNIVERSITY, CALIFORNIA,
November 8, 1894.

STUDIES FOR STUDENTS.

THE DRIFT—ITS CHARACTERISTICS AND RELATIONSHIPS.[1]

CONTENTS.

The topographic relations of the drift.
The body of the drift.
The terminus of the drift.
The topography of the drift.
The topography of the drift-covered area.
Relation of the drift to the underlying rock.
Significant features of the surface of the rock underlying the drift.
Striation and planation of the bed rock.
Shape of rock hills projecting through the drift.

THE TOPOGRAPHIC RELATIONS OF THE DRIFT.

The body of the drift. The drift is not confined to any topographic situation. Its vertical range may be hundreds of feet within a single mile. It occurs on the tops of mountains thousands of feet high, as well as on their slopes and at their bases. It covers hills of lesser magnitude, and mantles high plateaus and low plains with apparent indifference. It is found down to the level of the sea in some places, and is known to pass beneath it. Throughout all these topographic situations it maintains a tolerably constant character. Stratified drift often extends beyond the margin of the general drift-sheet. In such cases it is generally confined to the valleys leading out from the drift area. The stratified drift which is beyond the edge of the general drift-sheet is thus seen to maintain a definite relation to topography. As a general fact, the northern part of the drift-covered territory is higher than the southern, although elevated areas are not wanting near its southern limit.

[1] Continued from page 724.

The topographic relations of the great sheet of drift make it clear that the agencies which produced it must have been measurably independent of topography over the greater part of the drift area, but forces which were dependent upon topography carried stratified drift into valleys far beyond the borders of the area which is generally drift-covered.

Topographic terminus of the drift. Remembering that most of the drift was transported in a general southerly direction, it is a not insignificant fact that the line marking its southern boundary is largely independent of present topography. The drift does not rise to a given altitude and then fail; neither does it descend to a certain level below which it does not occur. In general, its southern boundary may be said to be lower than the larger part of the area which it covers to the north. In view of the direction in which it was transported, its distribution with relation to present topography is such as to indicate that in the process of distribution it was frequently stopped on a downward slope. The only escape from this conclusion would seem to lie in the assumption that the land surface has been extensively deformed since the drift was deposited, an assumption for which we have no warrant. In detail, the terminus of the drift is now on level lowland, now on level highland, now on a surface sloping toward the direction whence the drift came, and now on a surface sloping in the opposite direction. At some points, the terminus is found upon hilltops, while at others closely adjacent it is in the bottoms of valleys. The margin of the drift is therefore far from being horizontal. If it were allowable to suppose that the drift-covered area to the northeast had been elevated since the drift was formed, or that the driftless territory to the south had been depressed since that event, we might suppose that some more definite relationship than now appears formerly existed between altitude and topography on the one hand, and drift distribution on the other. But no general northward elevation or southward sinking will account for the topographic irregularity of the border of the drift. The character of this irregularity is such that, taken in connection with its surroundings, it is clearly not

the result of any post-drift alterations of level. The topographic irregularity of the drift border was original. It follows that the activities of the drift-producing agencies were not confined to a horizontal line along the outermost limit of their reach.

Topography of the Drift.

The topographic expression of a drift-covered country can hardly be said to be identical with the topographic expression of the drift, since the former is largely dependent on the topography of the subjacent rock. Strictly speaking, the topography of the drift is the topography which it possesses independently of its bed. It is the topography which it might assume if deposited on a plane surface. It should not be understood, however, that the topography of the underlying rock exerts no influence on the topography of the drift. Suffice it here to say that the topography of the drift varies within wide limits. Both stratified and unstratified drift may have surfaces which are nearly plane, though such surfaces are rather more characteristic of the former than of the latter. A plane surface of stratified drift is almost sure to have a slight inclination, tolerably constant both in degree and direction for any limited area. This cannot be said of the plane surfaces of unstratified drift, where such exist. By all degrees of gradation plane surfaces of either phase of drift may depart from planeness by taking on shallow depressions; but a plane topography interrupted only by depressions is much more characteristic of stratified than of unstratified drift. Again, the depressions in the surface of the stratified drift are more likely to be circular in form and more sharply defined than those in the surface of the unstratified, where such exist. In the latter case depressions are almost always accompanied by slight elevations, the counterparts of the depressions, the profiles of which are very gentle. If, along with the depressions, swells affect the surface of the stratified drift, as they sometimes do, they are likely to be more abrupt than the corresponding features of the unstratified drift. They generally have smaller bases for equal heights.

Either the stratified or the unstratified phase of drift may

have a topography of moderate relief and gentle profiles. But this is more characteristic of the unstratified than of the stratified phase. Either phase may have a rough topography, rough rather by virtue of the small size, steep slopes, and close juxtaposition of the elevations and depressions, than because of great relief. Extreme roughness of drift topography is perhaps as characteristic of certain special phases of stratified drift as of unstratified, but it is more characteristic of intimate associations of stratified and unstratified drift than of either alone.

If the average thickness of the drift be no more than one hundred feet, the average amount of relief for which it can be responsible is manifestly not great. The greater its thickness, the greater the variations of surface which it can produce, if irregularly disposed. Reliefs of one hundred feet or so, attributable to the drift alone, are not rare along certain belts of thick drift. Such differences in altitude may occur within the space of a few rods, but they do not characterize any considerable fraction of the drift-covered area. Reliefs of much greater range, belonging wholly to the drift, are seldom met with. Where so great relief occurs within narrow geographic limits, it is usually where deep, abrupt, kettle-like depressions are associated with equally abrupt hillocks.

The topography of the drift is not defined or described when its range of relief is indicated. Nothing more need be said concerning it at this point, than to indicate that one of its notable characteristics is the presence of multitudes of depressions which have no surface outlet. These depressions may have any depth up to a hundred feet or more. Reference is here made only to those depressions which affect the surface of drift, not to those for whose existence the irregularities of the surface of the underlying rock is largely or wholly responsible.

The depressions may be of any form, regular or irregular. They may be of any area, up to many square miles. Their slopes may have any degree of steepness, limited only by the angle at which loose material like the drift will lie. They may be closely grouped or widely scattered. Thousands and tens of

thousands of these depressions are marked by the swamps, ponds, and lakes of the northern part of the United States. Indeed, these features are so nearly co-extensive with the drift, that the line marking the limit of the latter may almost be said to be the line marking the limit of the former. The principal exceptions to this statement are the marshes and shallow ponds along coasts and sluggish streams outside the drift.

If it be remembered that the depressions in the surface of the drift have a wide range in the matter of area, shape, depth, and

Fig. 2. One type of drift topography. Drawn from photograph of drift surface, near Hackettstown, N. J.

abruptness of slope, a rough sort of idea of drift topography may be acquired by imagining at least an equal number of hills, of equally diverse sizes, shapes, and slopes, interspersed between the depressions. It is not to be understood that the depressions and hills are everywhere existent in the drift-covered area, or that they are everywhere striking, where they exist. It is to be remembered that there are areas of drift of great extent, the topography of which is essentially plane, and that there are other areas of equal extent where the topography is but gently rolling, and where the elevations and depressions are therefore not obtrusive. It is to be remembered further that in many parts of the drift-covered territory, the controlling element in the surface topography is

the topography of the underlying rock. Yet, in spite of all these exceptions, the presence of undrained depressions associated with elevations which, roughly speaking, are their counterparts, is one of the most distinctive features of drift topography. The topography of the drift is in sharp contrast to the topography developed by river erosion, for in regions whose surfaces are fashioned by river erosion the depressions are valleys, and each has an outlet. Every tributary valley leads to a lower, and the lowest leads to a lake, to an inland basin, or to the sea.

When the surface of the drift is rough, the roughness is dependent in part on the amount of relief, but more especially on the abruptness of the hills and hollows, and the closeness of their association areally. Where they have steep slopes and are close-set, even with but moderate relief, the topography appears rough. Where they are farther from one another, and possess gentler slopes, the topography may appear much less rough, even though the relief within broader areal limits be equally great. The topography of the drift, could it be distinctly separated from the topography of drift-covered areas, would be found to be measurably independent of the topography of the subjacent rock.

The Topography of the Drift-Covered Areas.

It is of consequence to distinguish between the topography of driftless and drift-covered territory. The topography of the latter is often, but not always, strikingly unlike that of the former. The topography of driftless territory varies within certain limits, and the topography of drift-covered territory varies within certain other limits. Sometimes the two types of topography vary toward a common limit. Under such circumstances they may closely simulate each other. In general it may be said that the most distinctive difference between the topographies of drift and driftless areas is the more perfect and more systematic development of the drainage lines upon the latter. This is made obvious in one way by the abundance of marshes, ponds, and lakes in the drift area, in contrast with their scarcity without.

It is made obvious in another way by the definite and systematic relations which exist between the elevations and depressions. In non-mountainous driftless regions, the depressions are usually river valleys, and the elevations inter-stream ridges. The common relationship of these features is such as to show that the inter-stream ridges are but remnants of a surface which has been roughened by the excavation of the valleys. In the drift-covered areas, on the other hand, this relationship does not always exist, and even where it can be made out, it is often obscure.

It is also of consequence to distinguish between the topography of drift-covered areas and the topography of the drift. The topography of the drift, it will be remembered, is the topography which it possesses independently of its bed. It is the topography which it might have if deposited on a plane surface. The topography of drift-covered areas is due partly to the topography of the drift *per se*, and partly to the topography of the rock below the drift. Either one of these elements may be the controlling one. Where the drift is thin and uniformly distributed, the topography of the drift-covered territory corresponds closely with that of the rock beneath. Where the drift is thick and irregularly disposed, the topography of the area it covers may be very unlike that of the subjacent rock. In extreme cases, and for limited areas, the drift may be so thick and so irregularly disposed that the surface affected by it preserves none of the topographic features of the underlying rock. In any case the existing topography is the resultant of the two elements. If the topography of the underlying rock has a relief greater than the average thickness of the drift, it will still determine the larger features of the resultant topography, though perhaps not its details. If the topography of the underlying rock possesses a relief which is slight in comparison with the average thickness of the drift, the latter may determine both the major and minor features of the resultant topography.

The drift and drift-free surfaces present many differences. Where there is no drift the valleys are likely to be more nearly straight. Here, too, the tributary valleys join their mains in a more regular way, and at a more nearly uniform angle, forming

more symmetrical systems. Abrupt turns and striking detours of streams are, on the whole, less frequent,[1] though this is not illustrated by limited areas everywhere. Within the drift area of North America, rapids, falls, and other evidences of youthful drainage are much more common than in adjacent driftless areas of comparable altitudes. The elevations between the valleys are more continuous in the driftless areas, unless the drainage system is so far advanced in its life-history as to have notched the inter-stream ridges, or to have cut them into isolated hills. The elevations and valleys stand in more definite and constant relations to each other; that is, the topography of the driftless country is a topography the details of which have been fashioned mainly by running water.

If it be true, as, on the whole, it probably is, that the drift territory has less relief than the driftless for corresponding altitudes, it is also true that its surface is often more "choppy," the hills being shorter and more noticeably huddled together. This characteristic is popularly recognized in such names as "short hills," "knobs,"[2] etc., names which have been locally used because of the striking contrast in shape between the discontinuous hills of drift, and the associated hills of greater length composed of solid rock (see Fig. 2). The choppiness of surface is by no means co-extensive with the drift. Where it is present, the drift, rather than the underlying rock, is the controlling element in the present topography. Drift hills are sometimes low and symmetrical in form, and their slopes gentle. They are sometimes more or less systematic in arrangement over considerable areas, but even then their forms do not generally stand in any definite relation to river valleys. Hills which are only drift-coated may bear a more or less obvious relation to the valleys, but hills composed entirely of drift are measurably independent of them.

[1] The abrupt turns of streams in their flood plains is not here taken into account.

[2] The name "Short Hills" has been given to a village in New Jersey where the surface is of the character here referred to. The term "knobs" is frequently applied to the abrupt and closely set drift hillocks. This term has also been popularly used in other relations to designate a very different type of topography.

In some regions, and over considerable areas, river erosion has so far modified the topography developed at the time of deposition of the drift as to reproduce a topography comparable in kind to that which affected the subjacent rock before the drift was deposited. In this case the characteristic features of drift topography have been destroyed. River erosion topography has been superimposed on the topography of the drift-covered area. Ridges and hills fashioned by streams working upon the drift, stand in that relationship to adjacent valleys which the laws of stream erosion determine.

Plane tracts may be brought into existence in very different ways. They occur in driftless as well as in drift-covered areas, Flatness, therefore, cannot be regarded as diagnostic, either of drift or of driftless regions.

It follows from the foregoing that the drift forces must have been such as were able to develop plane surfaces at some points, surfaces marked by more or less symmetrical drift hills which are measurably independent of valleys at others, and short, choppy hills, in still others. They must have been such as were able to modify, to all degrees, the pre-existent rock topography.

Relation of Drift to the Underlying Rock.

Where fresh exposures show the contact between any considerable bed of drift and the underlying rock, it may be seen that the drift does not generally grade into the rock. Especially where the underlying rock is hard, the plane of contact between it and the drift is generally sharply marked. Where the underlying rock is not indurated, the plane of contact is sometimes less well defined. Furthermore, where the underlying rock is hard, its surface is commonly firm and fresh. Signs of weathering are absent. Any weathered surface it may once have had before the drift was deposited was completely removed during that process. This relationship is shown in the accompanying diagram (Figure 3). It should not be inferred that the relationship between the drift and the underlying rock expressed in the diagram is universal, even where the drift is thick. It frequently does not

obtain where it is too thin to protect the rock beneath from considerable changes of temperature, and from the effects of those other disintegrating agencies which affect the surface to a depth of a half dozen feet. In such situations the surface of the

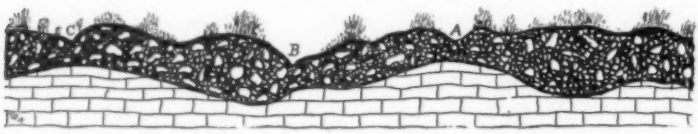


Fig. 3, illustrating the relation of drift to underlying rock. The line of contact is distinct, and the rock surface is not roughened by decay.

underlying rock may be much broken and weathered. If the rock be of such a character as to successfully resist weathering, its surface may be smooth and firm where the thickness of drift is very slight, or even where it is altogether absent.

The relation which the drift sustains to its underlying rock bed is therefore distinctly unlike that which the residuary earths of driftless regions sustain to the rock upon which they rest. In the latter case, as the designation "residuary earth" implies, the soil and subsoil have arisen chiefly from the decomposition and disruption of the underlying rock. All rock beds lack homogeneity to such an extent that their surfaces weather unequally. Their weathered surfaces are therefore uneven. The weathered

Fig. 4 shows relation of soil to rock, where the former has arisen by the decay of the latter. The line of contact is indefinite because of the irregular decay of the rock surface.

product of the rock—the subsoil—fills the little hollows on its surface, and penetrates the fissures and cracks, while the prominences of the uneven rock surface project up into the subsoil. The relationship referred to is illustrated in Figure 4, where the upper darker portion represents the residuary earths, and the lighter part

oelow the underlying rock whence the earths were derived. As shown in the figure, the upper surface of the rock is often so much broken, and so much mingled with the more earthy subsoil, as to make it very difficult to locate the plane of contact between them.

The true theory of the drift must explain its relation to the rock beneath. Any hypothesis which fails to explain this relationship must be incomplete at the very least. Any hypothesis with which this relationship is inconsistent, must be false.

Significant Features of the Surface of the Rock Underlying the Drift.

Striation and planation of the bed rock. Besides the characteristics referred to in the last paragraph, the rock surface beneath the drift, and especially beneath the unstratified drift, is frequently found to be polished and striated. Sometimes it is polished without being striated, but the two things usually go together. While these features are found at many points throughout the drift-covered area, and at all elevations at which drift occurs, they are not found everywhere where there is drift, and are rarely found beyond its limits. Where similar striæ on bed rock are found outside the limits of the great drift area, it is not without significance that they occur in lesser areas of drift. In North America, these lesser bodies of drift, with their striated stones, and with striated bed rock beneath, are in the lofty mountain regions of the west. The smoothings and the markings on the bed rock beneath the drift are identical in kind with those already noted as occurring on the bowlders of the drift. So exact is the correspondence, that community of origin cannot be doubted. The drift agencies, therefore, must have been capable of striating the rock beneath the drift, as well as the stony materials of the drift itself.

The striæ on the bed rock beneath the drift are generally approximately parallel in any given locality, and tolerably constant in direction over considerable areas. In a general way, the direction of striæ corresponds with the direction in which the drift has been transported. When large areas are studied, the

striæ are sometimes found to be far from parallel. Less commonly, this is true for small areas. Divergent and inharmonious as these various directions sometimes seem to be, fuller knowledge discovers a system in their arrangement. In many areas, the striæ are found to arrange themselves in systems. Within each system the striæ are found to be divergent from a common axis. Such axis is not generally a mountain range, or even a ridge. It is oftener a broad valley.

The systematic arrangement of the striæ, as developed in some regions, is illustrated by the accompanying figure (Figure 5), which represents, in a diagrammatic way, the arrangement of striæ on the rock surface beneath the drift of eastern Wisconsin. The striæ on the right-hand side of the figure appear to represent the marginal part of a second system, the axis of which is in the trough of Lake Michigan. In other localities, also, two similar systems of striæ lie side by side.

Within any single divergent system there may be local divergences from the common direction. In such cases, the divergences are almost uniformly associated with local topographic features. The striæ often have such a direction as to indicate that the agent which made them had a tendency to go around a hill or ridge, instead of passing directly over it. This tendency of striæ to veer round elevations may sometimes be observed about large and abrupt hills, while in the same locality lower hills with gentler slopes do not appear to have influenced the course of the striating agent.

Striæ are not confined to horizontal or gently inclined surfaces. They sometimes occur on steep slopes, on the vertical faces of cliffs, and, occasionally, even on the under side of overhanging rock masses. They sometimes occur in still more anomalous positions. In the face of the high bluff overlooking Cayuga Lake, for example, a horizontal groove in a vertical face is striated on its upper, lower, and interior sides. The groove in which the striæ occur retires eight inches into the face of the vertical cliff.[1]

Where striæ are absent from the surface of the rock beneath

[1] Seventh Annual Report, U. S. Geol. Survey, pp. 170, 173.

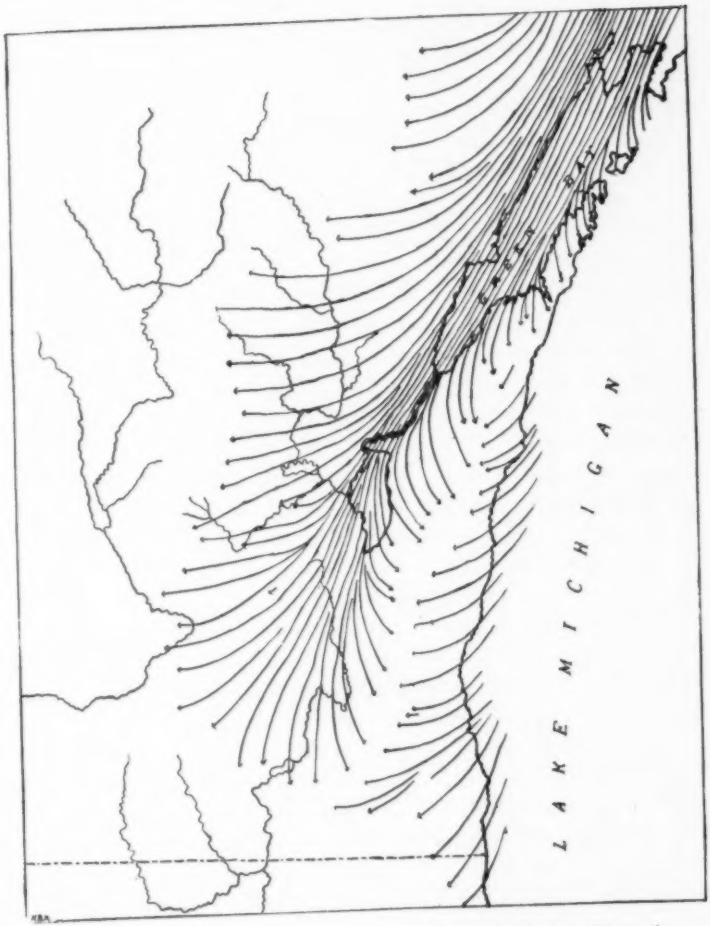


FIG. 5. Illustrating the general arrangement of striæ in Eastern Wisconsin.

the drift, their absence must be due to one of two things; either they were never formed, or they have been destroyed. Where the character of the underlying formation is such as to unfit it for receiving striæ, they could never have been developed. This would be true where the underlying formation is loose sand or gravel. Where the underlying rock is such as not to favor the development of striæ, but not such as to prevent their formation altogether, they may be rare. This might be true of rock which is unusually hard, and for this reason difficult of striation, or it might be true of rock which is very fragile and easily crushed. Where the underlying rock is ill-adapted for retaining striæ, they could not be expected to remain in great numbers, even if once developed. This would be the case where the rock is plastic, like clay, or where the rock is readily disintegrated. Again, striæ which once existed on rock adapted to receiving and retaining them may have been destroyed because of adverse conditions. Thus limestone received and has preserved striæ quite as well as any formation where the striated surface has remained deeply covered with drift. Where little or no covering has protected it, the striæ are absent, or ill-defined. It is reasonable to suppose that such surfaces were once striated, but that weathering has destroyed the marks.

The foregoing considerations help to explain why the striæ are not found at all points beneath the drift, even if the drift agencies and the polishing and striating agencies were the same, as we must believe they were. But there are places, and not a few of them, where striæ and polishing do not appear to have existed, even though the bed rock is of such a nature as to have favored their development and retention. In such cases the drift is often seen to rest, not on the solid rock, but on a layer of residuary material which originated in the decomposition of rock beneath. In this case the immediate substratum of the drift is really an incoherent earth, incapable of receiving striæ. In other areas where striæ and polishing are not known, their absence is probably apparent only. This is true in regions where the rock is so deeply buried that it is rarely seen.

Any acceptable theory of the drift must account for the divergent systems of striæ, for the local deflections from the general direction within these systems, and for the association of such deflections with local topographic features. It must also account for the occurrence of striæ on steep slopes, on vertical faces, on the under side of overhanging rock masses, and on the lower, upper, and interior surfaces of horizontal grooves in vertical cliff faces. It must be consistent with the absence of striæ and polishing on the rock surface at many points within the drift-covered territory, and must be mindful of the absence of the same sort of markings on the surface of the rock formations outside the drift. The phenomena of the striæ show that the drift agent or agents, or some of them, must have been such as could, under some circumstances, work with a large measure of independence of topography, at the same time that they were, under other conditions, locally influenced or even largely controlled by it. They must have been such as could have sometimes operated at great altitudes, as in the mountains of the west, without affecting the lower levels surrounding.

The shape of the rock hills projecting through the drift. In many places within the drift-covered area, but not everywhere, the rock knobs which project through the drift, or which are but slightly covered by it, possess certain characteristics which are not without significance. Such bosses of rock frequently have smoothed and rounded forms which are so distinctive that they have received a special name, *roches moutonnées*. In some regions each rock-prominence seems to be a *roche moutonnée*. In such cases, one side of each boss seems to be worn more than the others, and in any limited area it is generally the same side of each hill which shows the greatest wear. This fact must be taken into account in any attempt to explain the drift, for it is a phenomenon about as widely distributed as the drift itself, though not by any means to be seen at all points. The sides which are most worn are those facing the direction from which the drift forces moved, as shown by the direction of striæ, and by the direction in which material has been transported.

ROLLIN D. SALISBURY.

(To be continued.)

EDITORIAL.

In a personal letter from Bernard B. Smyth, of the Kansas Academy of Science, certain phenomena of the margin of the drift are described, which afford a criterion of age that is new, so far as we know. Mr. Smyth has recently been engaged in tracing the border belt of the drift in the vicinity of Topeka. This consists of a distinct well-defined train of bowlders with very little other drift. This had been traced to a point southwest of Topeka, where it disappeared. On making another attempt to recover the lost train, Mr. Smyth was surprised to find it in an unexpected place, resting on the bed-rock of the bottom of the valley of Shunganunga creek, covered up "*with about twenty feet of native prairie earth washed from surrounding hills.*" Further tracing showed that the train makes a sinus two miles deep and a mile and a half wide, beyond which it resumes its general course. This embayment Mr. Smyth attributes to the influence of a high point of land, which affected the ice rather by the reflection of the sun's rays than by physical opposition, since the line of bowlders does not approach the hill closer than one-third of a mile, generally not nearer than one-half of a mile. Analogous behavior of the ice in the vicinity of prominences was observed by the writer in Greenland. The point of most especial interest, however, is the burial of the border train of bowlders under so great a depth of native prairie earth from the surrounding hills. This indicates either that very favorable conditions are offered by this valley for the derivation and deposition of prairie earth, or that the bowlder belt has a very considerable age. At any rate, here is a basis of estimating both the actual and the relative ages of glacial deposits when so situated that the burying material may be discriminated as ordinary surface wash. From this region to Montana, the surface outside the drift border slopes toward it, and affords a wide field for the application of the method.

T. C. C.

Reviews.

Hussak's Geology of the Interior of Brazil. The Constitution of Brazil provides (Act 3) that: "An area of 14,400 square " kilometers is reserved to the Union on the central plateau " of the Republic, which shall be duly laid out, and in it " the future federal capital shall be established." In 1892 a commission was appointed to locate, explore, and report upon the region referred to. Dr. Luiz Cruls, director of the astronomical observatory at Rio de Janeiro, was chief, and Dr. Eugene Hussak, geologist of the commission. A preliminary report has been published under the title, *Relatorio parcial da commissão exploradora do planalto central do Brazil;* Dr. Hussak's résumé of the geology of the region is given on pages 105–130.

In view of the little known of the origin of diamonds in Brazil, what he says on this subject is of special interest. Agua Suja is a diamond mine in the southwestern corner of the state of Minas Geraes, four leagues south of Bagagem, the place where the famous diamond, the "Estrella do Sul", was found.

In the region between Uberaba and Rio Paranahyba the streams have cut down through sandstone to the underlying highly inclined mica schists. These schists contain masses and veins of quartz rich in tourmalines. The horizontally bedded sandstone resting upon the schist is unfossiliferous, easily decomposed, somewhat argillaceous and probably of later age than Carboniferous. In some places eruptive rocks (augite porphyry) overlie the schists, and in others they are contemporaneous with or later than the sandstone. The country is covered almost everywhere with recent water-worn gravels, sometimes loose, sometimes cemented. In the newly opened diamond washings these gravels form horizontal beds more than thirty-five feet thick, and divisible lithologically into four groups. The lowest of these groups rests upon the sandstone, and contains the heavy materials, big water-worn bowlders four to five decimeters in diameter, enclosed in fine

sand, and a great quantity of cobbles of augite porphyry, the size of one's fist at most. The big bowlders are of muscovite granite rich in tourmaline, of augite porphyry, of mica schist, of soft yellow sandstone, etc. The diamonds are found only in the sand containing cobbles of augite porphyry. The diamonds thus far found are small, but they are all of the first water. The following minerals are found with the diamonds: rutile, magnetite, tourmaline, pyrope, a single ruby, and, most abundant of all, limonite. Magnetite is the most characteristic of these minerals.

In regard to the original matrix of the diamonds found at Agua Suja certain circumstances suggest that they have originated in a manner analogous to those of South Africa. Hitherto it has been thought that the diamonds of eastern Minas were derived from the mica schists. The African diamonds, on the other hand, are from rocks of eruptive origin. The following are Dr. Hussak's reasons for believing Agua Suja diamonds to have an origin similar to the African ones:

I. The absence or rarity of many of the minerals that accompany the diamonds found about Diamantina.

II. The presence of others, such as the pyrope garnets, that are characteristic of the African mines, which, in a certain sense, indicate the presence of eruptive rocks, but which are rare or altogether wanting in the Diamantina washings.

III. The abundance and character of the magnetite pebbles indicate a highly basic rock of eruptive origin, and related to the African peridotite.

On the other hand it is admitted that the abundant fragments of mica schists and granite show that these have furnished materials to the Agua Suja gravels, and in the absence of positive proof to the contrary it is admissible that either of them may have furnished the diamonds.

The remainder of Dr. Hussak's report contains an interesting sketch of the general geology of the high plateau of Brazil. The rocks of the region traversed — southwestern Minas and southeastern Goyaz — he divides into two groups: first, the crystalline schists which consist of mica schist and itacolumite. These are cut by eruptive granites and are auriferous. Second, sandstones and Palæozoic clay shales, the latter enclosing gray limestones.

Those portions of Minas and Goyaz traversed—part of the great central plateau of Brazil—form a typical plateau of transgression.

After the formation of the fundamental complex of schists, which here consists of metamorphosed marine sediments, there were orographic movements which lifted, folded, and metamorphosed them; these movements were probably accompanied by granitic eruptions producing granitic zones and pegmatite dikes.

The granitoid gneiss zone of the Paranahyba valley and Entre Rios and the amphibole schists probably represent later granitic and basic eruptions connected with and modified by orogenetic movements.

After an interval of denudation came the sedimentary deposits which, upon elevation, form the region of schists, sandstones, and Palæozoic limestones between Santa Luzia and Formoza, and further to the north the lofty (1500 meters), flat-topped Veadeiros.

This second uplift closed the cycle of great geologic events for this region, and it has ever since been undergoing denudation. In the surrounding region, however, to the north and to the west in the Tocantins-Araguaya and the Xingú and Paraguay basins, to the east in the basin of the São Francisco, and to the south in that of the Paranan, enormous sedimentary deposits were laid down, which, by transgression, covered the margins of the old Goyaz island and extended over enormous areas in the basins mentioned. The later deposits have remained in a horizontal position. They seem to have begun in Devonian times and to have gone on with certain interruptions up to Mesozoic times. In the mining area about Uberaba the rocks are soft sandstones, and augite porphyries belonging to this great horizontal series. The sandstone is the continuation of the beds which in São Paulo overlie fossiliferous Carboniferous or Permian rocks; it is probably Triassic.

The characteristic feature of this formation in the Paranan basin is the abundance of eruptive rocks, suggesting a very active volcanic epoch. Denudation has deeply trenched the plateau, leaving a characteristic topography. Wherever erosion has cut down to the harder itacolumites these are left as high and rugged foothills with steep flanks. The limestone also resists erosion better than its associated rocks.

The last and newest formation of all these is the top dressing of gravel, which is not a marine deposit, however, but the result of atmospheric agents and the deposits of modern streams.

J. C. Branner.

Einleitung in die Geologie als historische Wissenschaft. By Johannes Walther. Jena, 1893–4.

In this new work of Professor Walther the inductive method receives a new and highly interesting treatment in its application to historical geology. There are, we are told, four principal methods of attacking the historical phases of geology, (1) the astrophysical method which begins with the earth as star-dust and studies its development from the speculative and mathematical standpoint of the astrophysicist; (2) the tectonic method which studies the structure of the crust and strives to reconstruct therefrom the changes which have taken place in it; (3) the experimental method in which geological phenomena are reproduced on a small scale in the laboratory; (4) the ontologic method.

The experimental method can, evidently, but rarely become a demonstration in the study of geologic phenomena, because we cannot often reproduce all the natural conditions and we know that the same results may often be produced by different methods. Thus coal may be procured by the rubbing or pressure of wood or by its imperfect combustion or by the action of acid upon cellulose tissue or by burning oil of turpentine. So also we may easily produce dolomite in the laboratory but to produce it from limestone and sea-water, observing the same conditions as those under which it is produced in nature has been the object of a great deal of unsuccessful experimentation. In many cases it is impossible for us to discover all the conditions under which the natural phenomena occur.

The experimental method must, therefore, be enlarged and at the same time held in check and corrected by a fourth method, the *ontologic method* as it is here called. This method consists in a word in making the earth our laboratory, in studying the processes by which geological history *is being made now*, and in making this study the point of departure for (introduction to) the study of historical geology. "We determine the origin of dead volcanoes by studying the formation of those now building; we form a basis for understanding the history of a fossil coral reef by examining a living reef; and the depth of water at which a fossil oyster bank was formed is approximated by a determination of the depths at which the genus *Ostrea* is now found living." (Introduction, p. xiii.)

Before entering further into the application of this method we

should bear in mind that like every other method it has limitations which the author does not fail to recognize. The most important of these seem to be the following: (1) Our observations of phenomena are often very limited. In spite of the numerous expeditions and deep sea dredging how small a fraction of the whole territory has been explored; (2) an important difficulty arises from the scattered condition of the literature of the subject which has been already greatly reduced by the present compilation; (3) more vital is the difficulty of studying forms which have no living representatives as the graptolites and the blastids and the fact that in general the farther back we go in geologic time the more difficult does it become to apply the ontologic method; (4) the most important limitation to this method, however, arises from the assumption which lies at the very root of it, namely, that factors affecting organic life and inorganic movement have remained the same in all ages. Can we be certain that the oyster now commonly found in from one to two hundred and fifty feet of water lived at the same depth in the Jurassic, or can we be sure that new factors have not entered in or old factors been lost which affected the mode of life and the deposition of strata? It becomes necessary then for the ontologically working historical geologist to be keenly alive to these possibilities of error and search in all his work to reduce the probable error to a minimum. If approached in this spirit this last objection would not prove as formidable as might at first be supposed and will decrease as *our knowledge of the laws of earth-history* become more and more complete.

Proceeding to the body of his theme the author agreeable to the nature of the ground to be covered divides his work into the study (1) of the formation of rocks, especially the sedimentary ones, (2) the mode of life of the marine organisms, and (3) the relations of the first to the second or the outside conditions of life and their effect upon the organisms (Bionomy); though for conventional reasons these topics are taken up in the reverse of this their more natural order.

Under the title "Bionomy of the Ocean" the author considers the distribution and conditions of life of marine organisms. As plants alone have the power to organize inorganic substances, it is important that we first study their conditions of life. They need light, water, carbonic acid, and chromophyll, without which the processes of assimilation cannot take place. As experiment has shown that light waves capable of

effecting chemical changes do not penetrate the water deeper than 400 meters and as the other conditions of assimilation are met above this line, it is proposed to distinguish a *diaphanic* region including the land and the water to a depth of 400 m. and inhabited by assimilating organisms and an *aphotic* region including the ocean and lakes below the assimilation-line and the dark caves of the crust, where plant life is impossible. Temperature limits—85° C. to 3° C. for water organisms—restrict greatly the distribution of life in the diaphanic region.

Upon a somewhat different basis of classification are next considered the life-zones of the ocean (divided first into oceanic basins and second into shore, shallow, and deep sea zones), and the kind of life inhabiting each (the author following Haeckel in dividing the ocean forms (Halobios) into Benthos, or bottom forms, Nekton or active, swimming forms and Plankton or passive, floating forms with numerous subdivisions).

Intimately connected with the question of environment in its relation to life is the facial development of the ocean bottom. Thus we find that certain forms as Mytilus and Mactra are found upon a mud bottom, other forms as Anomia and Spondylus love a gravel bottom. A change in bottom from any cause will cause a change in the fauna—a migration. The influence of the bottom extends, however, not only to the plants and animals living directly upon it but also to the Nektonic forms which feed upon certain plants and further to the animals of prey wno live upon the animals (of both Benthos and Nekton) who frequent the same region. Further than this the fact that fish pick out a certain kind of bottom on which to lay their eggs causes them to frequent certain places during the spawning season.

A great many interesting questions relative to the effect of environment are discussed and by numerous facts illustrated in the following sections on the influence of light, of temperature, of salt percentage, and the effects of tides, waves, and circulation of the water upon the living organisms. The formation of oceanic islands and all those movements of the earth's crust which alter its position and cause a relative or absolute change in the sea-level have an immediate and vital influence upon all life within the region of change, because it affects at once the various conditions under which the organisms have been living. This constant change of environment by com-

pelling the faunas and floras to migrate, or die, or by modifications to adapt themselves to their surroundings becomes a powerful factor in the production of new varieties and the origin of new species.

Part II. takes up the mode of life of the marine fauna, especially from the standpoint of their importance to the palæontologic geologist. In order that the working geologist may not underrate the sources of error in his work the author very wisely discusses first the various zoölogic groups to show what ones are by reason of the absence or the unstable nature of the hard parts incapable of preservation. The following sections discuss for the most part the conditions favorable to the life of the various animals which are taken up in their zoölogic order beginning with the Foraminifera. In this section of the book the tables showing the maximum and minimum depths at which various species have been found by dredging are an especially prominent and valuable feature. In the section on the Cephalopods especial attention is called to the fact that the shells having air chambers by being able to float for long periods may be readily driven to great distances after the death of the animal and become fossils in a totally different region from that inhabited by the animal during life and in varying sorts of rock according to the nature of the bottom upon which the shell chances to drift. He points to the fact that the living *Spirula* and *Nautilus* are restricted to narrow boundaries on the sea bottom and that the animal is rarely seen. At the same time the shells of the dead *Nautilus* and *Spirula* are found widely scattered on tropical strands far from the home of the living animal. These thoughts applied to the very important fossil group of the Ammonites mean that their shells *tell us nothing* of the conditions under which the Ammonites lived but give us most valuable means of making exact correlations; for if as we suppose the Ammonite shell on the death of the animal rose to the surface and was carried for many days hither and thither and finally filled and sank, the shells would be scattered here and there over the entire ocean bottom and deposited in sediments *all of the same* age. So confident is the author of this that he believes that the Ammonite shells mark *not only homotaxial but actually homocronial periods*.

Part III. considers the formation of rocks upon the present surface of the earth. According to their mode of formation mechanical, chemical, volcanic and organic deposits are distinguished, and the distribu-

tion of the various rock facies over the earth's surface is indicated. This portion of the book which makes up the major part of Part III. (pp. 543–966) is largely systematic and classificatory in its nature and is filled with a large array of facts and observations on the formation of recent rocks and their distribution which cannot fail to be of great value to the working geologist. Here again the author calls brief attention to the alterations which the recent rock formations undergo in becoming fossil the knowledge of which is essential to the understanding of fossil deposits. Two classes of such changes are distinguished,—*metamorphism* and *diagenism*. By metamorphism is understood alterations caused by mountain pressure and volcanic warmth; and diagenism is defined (p. 693) as "all those physical and chemical changes which occur in a rock after its deposition without the action of mountain pressure and volcanic warmth." The book appropriately closes by outlining the possibilities of a *comparative lithology*. Throughout the book is urged the necessity of the historical geologist giving equal prominence to the study of the conditions of formation of the rocks and the conditions of growth of organisms. We make prominent the study of the correlation of faunas in historical geology and we should not neglect the study of the correlation of deposits. As comparative anatomy based upon the correlation of organs is the most important aid to palæontologic work of reconstruction, comparative lithology based upon the correlation of rock formations would prove a valuable aid to the study of historical geology and the reconstruction of earth history.

In the chapters on equivalence of the rocks, correlation of facies and changes in facies the author points the way to a scientific study of comparative lithology and lithological correlation of sediments and indicates some of the laws governing the deposit of sediments, which complicated as they are, are important enough to be worthy of careful investigation.

On the whole the work is a thoughtful and carefully worked out presentation of his theme, evincing long and careful work of observation and compilation and a just appreciation of the peculiar advantages and the disadvantages of ontologic methods of research in historical geology. The two factors—the history of fossils and the history of the rocks—are given equal prominence, and it is everywhere emphasized that the one cannot be studied successfully without the aid of the other.

E. C. QUEREAU.

Geologische und geographische Experimente. Heft III., Rupturen, Heft IV., Methoden und Apparate. By E. REYER, Leipsic, 1894.

In connection with Professor Walther's book it is interesting to note the appearance of the last pamphlet by Professor E. Reyer, of Vienna, representing the *experimental method* in geology. The two preceding papers, which appeared two years ago, and which will be more or less familiar to the reader (*Ursachen der Deformation und der Gebirgsbildung*, Leipsic, 1892; *Geologische und geographische Experimente über Vulkanische-und Massen-Eruptions*, Leipsic, 1892), introduced Professor Reyer's experimental work, especially in the reproduction by artificial means of the phenomena accompanying mountain-building and eruption. The last paper, just received, comprises two sections. The first deals with the various phenomena of cracking and gaping of the crust caused by torsion, lateral pull, lateral pressure, or vertical movement. The phenomena of rupture found in regions of crustal movement or of metamorphism are reproduced here on a small scale. These experiments recall those of Daubrée, but are an improvement over his work in so far as in the present case the materials used correspond more nearly to the materials in nature. In the second part of this paper, where the author gives to the public his methods of experimentation, and the apparatus constructed and employed by him in his laboratory, we find that clay, loess, loam, and gypsum, or some adhesive substance, are the most prominent constituents used, and that ice, glass, or harder substances, do not find a place. The advantage in using softer substances is obvious, for the smaller the scale of the experiment the finer must be the material used and the less, therefore, should be its cohesion in order to make the relation of cohesion to the natural forces, as gravity, correspond to their relations in nature. If the relation be a correct one the action of gravity for instance will produce the same result (of faulting, flexure, etc.) in the reduced laboratory experiment as in the large process in nature. In experiments of torsion with harder substances, as glass or ice, gravity alone produces no effect because the cohesion of the glass is so great. If, however, we have a mixture (of fine-grained silt or gypsum with water) of the proper consistence arranged in thin layers (strata) and leave one part unsupported, the action of gravity alone produces the desired flexure, faulting, or twisting as Professor Reyer has shown.

Unfortunately the lateness of the receipt of the paper prevents a more special account of apparatus and methods. The field, however, is full of promise. It would seem that at present a chief desideratum in this kind of work is to so choose the conditions of experimentation in the laboratory that, if not the same, they may be at least comparable to natural conditions as far as possible, that the results may be suggestive less of how the process may take place and more of how in nature it did take place. The work of Professor Reyer has been of undoubted value, and will, we hope, stimulate to further careful investigation in this direction.

E. C. QUEREAU.

Analytical Abstracts of Current Literature.

Verlauf Der Grönland-Expedition der Gesellschaft für Erdkunde. Dr. Erich von Drygalski. Verhandlungen der Gesellschaft für Erdkunde zu Berlin, 1893, Nos. 8 u. 9.

This article is mainly a sort of itinerary with little geological detail. The glacial investigations referred to were carried on chiefly on the mainland east of Disco. The author emphasizes the fact that the surface of the inland sea near its edge is much dissected by valleys cut by surface streams, and that there are upon the ice many pools and little lakes due to melting of the ice beneath patches of dust. In the warm season there are many lakes about the border of the ice held in on one side by the ice. With the first sharp cold the ice cracks so as to let the water escape. The author's microscopic study failed to discover any essential difference in structure between glacial ice and lake ice, though the fjord ice was somewhat unlike both. Dr. von Drygalski thinks that the contained water alone gives to glacier ice the power of movement, and that, therefore, there is no motion without a melting temperature. It is thought that the melting temperature maintains itself at the bottom of the ice by virtue of the transfer of heat from the upper surface during the melting season. Since the upper part of the ice must be below the melting point during a large part of the year, it is thought that movement depends more on the lower than on the upper layers. The author is doubtful of the truthfulness of the comparison between ice streams and rivers. The temperature of the mass is thought to fluctuate about the freezing point, and its work and motion are thought to depend upon the change from a solid to a fluid condition, and *vice versa*.

R. D. S.

The Geology of Angel Island. F. Leslie Ransome. (Bulletin Geological Department of University of California, Vol. 1, No. 7.)

Angel Island is about a square mile in extent, and lies in San Francisco Bay, three and one half miles northeast of San Francisco. The larger portion of the island is occupied by the San Francisco sandstone, which contains an abundance of plagioclase and other non-quartzose fragments. Interbedded with the sandstone are numerous masses of jaspery rock elsewhere denominated "bedded jaspers," but the discovery of an abundance of remains of

siliceous organisms makes the term "radiolarian chert" more applicable. Both sandstone and chert have been locally metamorphosed by the invasion of eruptive rocks. The term Fourchite is doubtfully applied to an intrusive sheet or sill invading the San Francisco sandstone, some portions of it consisting of a breccia, other portions having an imperfect spheroidal structure, while the main body is massive evidently representing a true sill and not an interbedded flow. Bright blue amphibole, with pleochroism of glaucophane is a noticeable feature. It is also remarkably free from the usual accessory minerals of basic eruptive rocks. Alteration along the contact zone has resulted in the development of a glaucophane schist. Serpentine which occurs as a large dike traversing the island from northwest to southeast was derived from a rock composed wholly or mainly of diallage and incloses masses of a gray rock resembling diabase. The glaucophane schists were formed from the San Francisco sandstone by metamorphism. Evidence controverts the view that the radiolarian cherts (bedded jaspers) represent ordinary shales silicified by regional metamorphism. The serpentine is in no sense a metamorphosed sediment. The appendix contains descriptions of radiolarian remains found in the chert.

C. H. G.

Geological Survey of Missouri. Report on the Bevier Sheet. By C. H. GORDON. J. E. TODD and H. A. WHEELER, contributors. Report on the Iron Mountain Sheet. By A. WINSLOW, E. HAWORTH, and F. L. NASON.

The above reports, issued by the Missouri Survey under the direction of Arthur Winslow, State Geologist, constitute the second and third of the series of sheet reports, of which the Higginsville Sheet was the first. The present reports are issued in large octavo, uniform with the other publications of the survey, instead of the same size as the atlas sheets, as was at first planned. Each sheet comprises an area of one fourth of a square degree. The scale is 1:62500, or about one inch to a mile. The topography is indicated by twenty feet contours. A sheet of cross and columnar sections accompanies each map. The work has evidently been carefully done.

The Bevier sheet comprises the southwestern part of Macon county, with portions of Chariton and Randolph. The topography is due entirely to stream erosion. The rivers have sunk their valleys to a moderate depth in a wide stretching plain, the remnants of which are still well preserved in the broad inter-stream surfaces.

The stratified rocks of the region belong to the Coal Measures series, the deposits of the Middle and Lower stages being represented. Within the state, however, no widely recognizable horizon separating the two has been identified. The strata dip gently to the southwest, but there are local depart-

ures from this dip. Five beds of coal are recognized, two of which—the Bevier and the Mason City beds—can be profitably worked. The former of these is the most important. Its estimated available tonnage within the limits of this sheet is 336,000,000 tons.

The report on the Quaternary geology is by Professor Todd. Three divisions are noted, viz.: 1. Pre-glacial or basal clay, a light gray clay, without northern pebbles, and of no great surface extent. 2. Drift or till. The erratics comprise granites, greenstones, and a red quartzite identical with the Sioux quartzites. The last seems not to be distributed much further east than the area of this sheet. 3. A gray, loamy clay, which is intimately mixed with fine sand, and contains a few well-worn pebbles and calcareous concretions. This formation is McGee's "gumbo." Professor Todd considers it the equivalent of the higher loess into which it appears to grade. Much detailed information is given by Professor Wheeler concerning the economical values of clays and shales of the region.

The rocks present in the area covered by the Iron Mountain sheet are, 1) crystalline, massive Archean rocks, which are divisible into basic eruptives, occurring in the form of dikes, and acid eruptives, including both granites and porphyries; 2) crystalline stratified Algonkian rocks, chiefly conglomerates and slates, including the iron ore bed of Pilot Knob; 3) clastic Paleozoic limestones and sandstones. The economic interest of the region centers chiefly in the iron ores and building stones. Thorough exploration has shown that the Iron Mountain ore deposit is practically exhausted. The same may also be said of the Pilot Knob deposit.

H. B. K.

The Granites of Cecil County in Northeastern Maryland. By G. PERRY GRIMSLEY. (Jour. Cin. Soc. of Nat. Hist., Vol. XVII., Nos. 1 and 2, April, July, 1894. Thesis for Doctorate, Johns Hopkins Univ.)

The rocks of this region are holocrystalline with a northeast strike and a highly inclined dip to the southeast. The rock is of a light color with dark biotite arranged in more or less parallel lines. This foliation runs northeast while the dip is nearly vertical. Toward the gabbro contact on the north the feldspar of the granite is replaced in part by hornblende and biotite along with an increased amount of magnetite. Near the contact, bowlders of sheared and squeezed chloritic rock occur, together with dark oval patches of basic constituents. The latter are considered basic segregations rather than inclusions of foreign rock. Other rock types are diorite and staurolitic mica schist.

As a result of dynamic action, old minerals have been more or less metamorphosed and new ones developed, with the production of a secondary foliated structure. Of new minerals epidote is especially well developed. In

the replacement of feldspar by epidote, the host apparently exerts no orienting influence on the epidote as is often stated to be the case. The epidote is often arranged in zones and sometimes is concentrated in a rim within the feldspar individual. The explanation of this is sought in variations of chemical composition within concentric zones of a single feldspar crystal. The alteration of feldspar to muscovite is much less frequent than to epidote.

The staurolitic mica schist separating the areas represents a sedimentary deposit more ancient than the granites and probably owes its highly crystalline character to contact metamorphism.

The study of granite soils with the aid of the miner's pan showed the presence of a number of minerals not noticed in the thin sections.

C. H. G.

Erosion in the Hydrographic Basin of the Arkansas River above Little Rock. By J. C. BRANNER. (An. Rep. Geol. Surv. of Ark., 1891, Vol. II.)

The observations on the erosion in the Arkansas River basin, while not as exhaustive as the State Geologist desired them, owing to limited resources at his command, they nevertheless furnish a valuable addition to the literature on this subject. The physical and chemical character of the sediment is described, and a number of analyses given. The tabulated results of the amount of material carried in suspension and the amount carried in solution for each month in the year are given.

More than twenty-one million tons are carried in suspension and nearly seven million tons, or nearly a third as much in solution. In November during very low water, the amount in solution was six times that in suspension, while in May and June during high water, the amount in suspension was more than five times that in solution. The results are compared in part with those of other rivers.

Other papers in the same volume are Elevations, Magnetic Observations, and Bibliography, by J. C. Branner; Mollusca, by F. A. Sampson; Myriopoda, by C. H. Bollman; Fishes, by S. E. Meek; The Geology of Benton County, by F. W. Simonds and T. C. Hopkins; and Geology of Dallas County, by C. E. Siebenthal.

The Dallas County report is accompanied by a topographic map, and contains a discussion of the topography and the general geologic features; but the chief point of interest is the description of the potter's clays. It contains numerous analyses, a list of the occurrences of the clay deposits and a history of the pottery industry in the county. The pottery clays of other parts of the state, along with the other valuable clays of the state, will be described in a forthcoming volume on clays by the State Geologist.

T. C. H.

The Tertiary Geology of Southern Arkansas. By G. D. HARRIS. (An. Rep. of the Geol. Surv. of Ark., 1892, Vol. II., pp. 207; 1 map.)

All the Tertiary deposits of Southern Arkansas are classed in the Eocene series and subdivided into the Midway, Lignitic, Claiborne, and Jackson stages, using the nomenclature of the neighboring states. These correspond, in part, at least, with the Lafayette formation of McGee and the Orange sands of Hilyard, but Professor Harris prefers, for reason given, not to use these terms. Each of the stages is discussed in detail as to distribution, topography, and organic remains. The oldest known Tertiary deposits in the state are included in the Midway stage and contain a fauna similar to the Midway limestone in Alabama. The Lignitic stage lacks molluscan remains, but fossil leaves are abundant. Molluscan remains are not abundant in the Claiborne stage, but are in the Jackson stage. The Tertiary-Cretaceous border is changed in a number of places from Hill's map in 1888. The Cretaceous is found farther to the northeast than formerly supposed. Seven plates of typical fossils are given and thirty-four figures illustrating the stratigraphy of the area. The purely economic features of the area will be discussed in a future volume of the Survey publications. T. C. H.

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The Granites of Cecil county in Northeastern Maryland. (A thesis accepted for the degree of Doctor of Philosophy, by the Johns Hopkins University, June, 1894.) 50 pp. with Plates.—From the Journal Cin. Soc. Nat. Hist., April and July, 1894.

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A Study of the Cherts of Missouri. 9 pp.—From the Am. Jour. Sci., Vol. XLVIII., November, 1894.

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Ueber die Grenzzone zwischen Hochalpen und Freiburger Alpen im Bereiche des oberen Simmethales. 7 pp.—Separat-Abdruck aus Berichte der Naturforschenden Gesellschaft zu Freiburg, Band IX., Heft 2, 1894.

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